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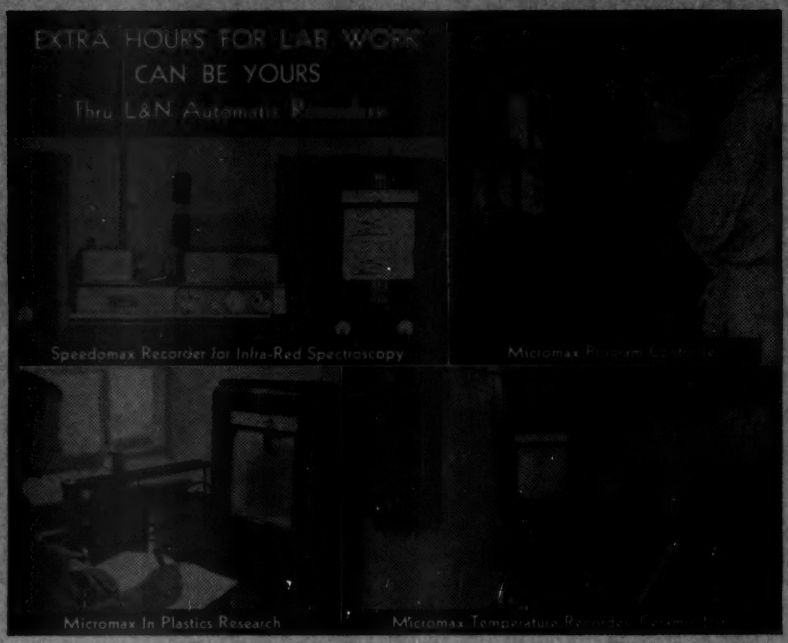
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Journal
of
The Franklin Institute

Devoted to Science and the Mechanic Arts

Vol. 247 **JUNE, 1949** **No. 6**

THE STORY OF THE FRANKLIN INSTITUTE*

BY

JAMES H. ROBINS[1]

MEMBERS AND FRIENDS OF THE FRANKLIN INSTITUTE:

When I was asked to tell the story of The Franklin Institute tonight I was genuinely puzzled, for I am no authority on the history and accomplishments of this grand institution, nor have I any standing as a speaker. This puzzlement remained until I had the opportunity to read the first quarterly report of the Institute dated 125 years and 5 days ago, which told of how The Franklin Institute chose its first speakers. The report said this: "Your Board have been anxious to commence immediately the usefulness of the Institute by the establishment of popular lectures during the present season, but as the funds of the Society are still very low, they have had recourse to the zeal of their members and are happy to state that the introductory lecture will be delivered on the 28th inst. by Dr. Robert M. Patterson." When I discovered also then that my great-great grandfather was the first Chairman of the Board of Managers and that his son, my great grandfather, was the Dr. Patterson who gave the first lecture, it finally dawned on me that the present management reckoned that perhaps I had inherited enough of that eager-beaver spirit to undertake the job.

FOUNDATION

Every worth-while institution starts from an idea and an urge. Late in 1823 a 22-year-old Maine Yankee found himself in Philadelphia, the owner of a workshop, but without any mechanical education and, as has been said, scarcely a mechanical idea. But he had gumption, he

* Lecture presented at the Stated Monthly Meeting of The Franklin Institute, April 20, 1949, on the occasion of the celebration of the 125th anniversary of the founding of the Institute.

[1] President, The American Pulley Co., Philadelphia, Pa.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

had organizing talent, and a lot of nerve. He tried to join an association of mechanics which gave courses, and was blackballed on the ground that he was too much of an ignoramus to qualify. He decided to organize a Society open to the public, called a meeting, and nobody came. He called another meeting and again nobody came. Instead of dropping the idea, he joined forces with a young U. of P. professor, who had also tried to start a scientific institution. In union there must have been extra strength, for these two youngsters, Samuel Merrick and William Hypolitus Keating, at last gathered a group, mostly young, mostly unknown, who undertook to help start the ball rolling. It appears evident that the founders of The Franklin Institute, as it was named, deliberately aimed to bring together high-faluting and low-faluting people interested in science and the mechanical arts. As it was once put, a platform was needed broad enough and strong enough to accommodate professor and layman, master and workman, side by side without incommoding either. In brief, an institution was wanted which should have inscribed on its cornerstone "Science with practice, practice with science."

This young group went about organizing their Institute in a practical and effective way that could be a model even today. They chose 1500 names from the City Directory and called a meeting in the County Courthouse which was filled to overflowing, and within a year the new Institute had almost 500 members. They are all listed, with their occupations, in the first annual report of the Institute, and to give you a quick idea of how well the founders succeeded in bringing a mixed group together behind a common interest, I am going to read off some occupations of those first members: gold-leaf manufacturer, smith, music composer, president of the U. S. Bank, stock and exchange broker, skin dresser, powder manufacturer Brandywine, whip corder, Judge of the Supreme Court, sea captain, apothecary, tallow chandler, bricklayer, agriculturist, dentist, sugar refiner, County Treasurer, Mayor, Recorder of Deeds, Prothonotary of the Supreme Court, Chief Justice, Professor of Obstetrics, architect, marble mason, sculptor (get those two), reed and shuttle maker, livery-stable keeper, pianoforte maker (and I'd like in his case to quote his perfect name, "Mr. Thomas Loud").

Incidentally, there were two Trumans in the list.

I just can't resist the temptation to spend some time telling about that first year of the Institute because of the clear thinking, the organizing power, the ability at promotion, and the foresight which those oldtimers displayed then, and which actually provided the framework upon which The Franklin Institute operates even today. They knew what they were after and they moved in on their objectives with the sure confidence of a Sergeant York advancing on a machine-gun nest.

They recognized the importance of *pride* to high quality of workman-

ship in products and they built upon that fact in several ways. They decided to invite all new inventions to be submitted to a committee of the Institute for examination. Originally this was a Board of Examiners of Inventions, to advise inventors on whether they, so to speak, had anything. At various stages of its existence it has made scientific investigations on its own hook or upon request. For a long time it was presided over by Dr. Alexander Dallas Bache, great grandson of Benjamin Franklin. The members serve without compensation. That committee has been carried right down to this day. Its present form is the sixty-man Committee on Science and the Arts which, without a break during the 125 years, now awards the present-day formidable array of medals on Franklin Institute Medal Day. So far as I know, there is no other group in the world resembling this able, objective and superbly qualified group of men who continuously comb the field of invention and technological accomplishment and reward the greatest of these in a way which long ago achieved world-wide confidence and prestige.

Those oldtimers believed also in promoting perfection of workmanship in old products as well as the invention of the new. This led to their decision to hold an exhibition each October in Philadelphia. They were the first exhibitions in the United States.

They decided to form a library—a scientific, specialized library—and carried it through successfully; that library too exists to this day on a vastly expanded scale.

They decided also to create a cabinet of minerals and models of machines. From that small beginning we now have the fine museum which is the great feature of this building.

Still another initial activity was the launching of an active correspondence with all known similar societies everywhere, for the systematic exchange of information, which likewise has continued for 125 years and has resulted in our library acquiring by exchange an immense collection of scientific publications and documents of high historical and practical value.

They decided too to publish a Journal and within the year the Journal of the Franklin Institute was launched and survives to this day in the form with which, whether you understand its contents or not, you nevertheless are familiar.

But perhaps the most significant and far-sighted idea in the entire first quarterly report was contained in this paragraph: "There are objects of still greater importance, which the Board entertain a hope may at some future day be within the means of the Society; foremost among these would be the establishment of an experimental workshop and laboratory, . . .: but this would require a much larger sum of money than the Society has at present at its disposal. All that your Board will therefore venture to suggest on this subject is, that the Society should

not lose sight of it, but embrace the first opportunity of stamping upon their Institution the greatest degree of usefulness. . . ."

That report closes with an incident which takes us straight back to those horse-and-buggy days. It tells of the resignation of John C. Browne of Kensington, whose distance from the place of meeting rendered it inconvenient for him to join the Board.

The first regular meeting place was in good old Carpenter's Hall near Independence Square, but during that amazing first year the Institute began to plan for a larger permanent building, and the corner-stone was laid on June 8, 1825 for a building on Seventh Street between Market and Chestnut, where the Institute remained for over a hundred years. You probably know that it is now the Atwater Kent Museum.

EXHIBITS

We should realize that in 1824 American manufacturers and artisans were, by and large, struggling to obtain public recognition for their products and skills in competition with the well-established imported products, mostly English. They had the same growing pains, same personnel problems, and the same hurdles of consumer resistance to overcome that newcomers have in the present day. To the infant Pennsylvania industries and craftsmen of the day that first Franklin Institute exhibition was a shot in the arm. The opportunity to display their wares under the sponsorship of such a broad cross-section of successful Philadelphians was a high stimulus and a priceless opportunity to put their best foremost, and indeed to surpass their best previous performances. In comparing the technique of those early Franklin Institute exhibits with the beauty contests at the Shore in our own time, one is easily convinced that there is nothing new under the sun—unless it be area of exposure to the public gaze.

Following the first exhibit in October, 1824, exhibits were held every year or two until 1858 and were discontinued then only through the lack of suitable quarters. After a gap of a couple of decades the Institute put on a 50th Anniversary Exhibit in an abandoned freight station of the Pennsylvania Railroad at 13th & Market Streets. This exhibit was a tremendous success: there were over a quarter-of-a-million paying visitors, 1251 exhibitors, 281 moving machines, and last but not least, a $52,000 profit.

It acted as a sort of a warming-up for the great Centennial Exposition of 1876; and in fact The Franklin Institute had quite a hand in that too, for 'way back in 1869 the Institute had adopted a memorial and resolution to Philadelphia City Council proposing a Centennial Exhibition.

Not content to rest on those laurels, the Institute staged what was in effect a 60th Anniversary, in the form of an International Electrical Exhibition in 1884. This was the first exhibition in America devoted

exclusively to the electrical arts, and it likewise was a smash hit. To this exhibition flocked foreign scientific men of world-wide reputation, and a number of scientific societies held their meetings in connection with the exhibition that year. That exhibit too drew the best part of 300,000 people and ended up nicely in the black.

For this exhibition the Pennsylvania Railroad came through again by lending ground and a building out just west of the present 30th Street Station. When the Pennsylvania abandons Broad Street Station in the not-far future, precedent evidently says that it is up to the Railroad and The Franklin Institute to get together on another exhibition. What the theme will be remains to be thought of. Perhaps it could be a competitive display of the relative merits of rail and automotive transportation, with freight trains fighting it out with trucks, passenger cars with autos and trailers, and the Pennsylvania dining-car service trying conclusions with the protegees of Duncan Hines.

After 1884, however, the Institute stepped aside from the exhibit field in favor of specialized shows, on account of the immense expansion in the whole field of technology. The present-day successors to those great exhibits are the special quickie displays which the Institute now puts on from time to time and the permanent one-company industrial exhibits, thanks to the fine cooperation of a number of enterprising concerns.

EDUCATION

Fresh on the heels of that astonishing first year of the Institute, it took it upon itself to organize the first high school in Philadelphia, the Franklin High School. Within a short time day and evening classes were being held in the sciences and in languages, attended by over 300 scholars as early as 1827. The City patterned the Central High School on this pioneering effort and after the school system was in full running order, The Franklin Institute cut back on the conventional high-school activities, but maintained a famous School of Mechanical Drawing for 99 years.

Threaded into this century of educational activity were such ventures as a stenographic school in 1876 and the foundation of what has since become the School of Design for Women. For a while the Pennsylvania Museum and School of Industrial Art were housed by the Institute and cooperated closely with it. Many eminent men got their first training in one or another of these various schools, or, like Professor Elihu Thomson, taught classes in them.

As you well know, the lectures, launched on Wednesday evenings by my venerable great grandpapa, have continued unbroken. They are still given on Wednesday evenings. In the span of 125 years, it is safe to say that the greatest scientists in the world have at one time or another spoken or lectured at The Franklin Institute.

SOME FIRSTS

Just a few "firsts" for the Institute include Daguerre's paper, the first in English on photography, in 1839; Emile Berliner's talking machine of 1888; the voting machine in 1901; dial telephones in 1909; and the inauguration of transcontinental telephony in 1916. In connection with that affair Phil Staples, until not long ago both President of The Franklin Institute and also of the Bell Telephone Company, tells a story. In 1916 he was a young hopeful in the Telephone Company organization and he and others were given the job of personally delivering flossy invitations to this ceremony opening up the line to San Francisco, which was a tremendous achievement in those days and was the pride and joy of the A. T. & T. He took one of these invitations to a leading Philadelphia citizen of the more conservative variety, who perhaps had himself never ventured beyond Paoli. When this gentleman saw the invitation, he growled at Phil: "Why in the world would anybody ever want to *telephone* to *San Francisco?*"

INVESTIGATIONS

It was natural that an organization in The Franklin Institute tradition should be drawn into various objective investigations at one time or another. One of its first efforts in this direction was an investigation of how to build the most efficient water wheels. A little later, when steam boilers were blowing up right and left, and no one knew how to stop them, it made a study of boiler explosions and how to design and rate safe boilers, which achieved world-wide acceptance. This is believed to have been the first U. S. Government-subsidized research ever carried out. This study perhaps led it to fundamental investigations of the strength of materials of construction, which were also basic contributions to modern design of both machines and structures.

It started one of the first Weather Bureaus. Its contributions to the standardization of screw threads are well known to every mechanical engineer. (What problems of standardization there are! After the Institute first offered a complete system of standard screw threads to the world, it took 85 years and the threat of a third World War to get British and American manufacturers and engineers together on an international standard.)

A few years later The Franklin Institute sponsored an official study of the Philadelphia city water supply. That report reads like the present day: we all know that the city was still at it 70 years later with no conclusive results. Having stopped people getting killed by boiler explosions, it took on another life-saving problem, officially known as "Conflagrations and deaths from petroleum in lamps." This was in 1873. Evidently the Institute thought it was time to warn people to keep cows away from lamps or lamps away from cows, for we all know

the story of the Chicago fire of 1871. Soon afterwards the Institute looked into the whole subject of Schools of Science for people of limited means, in which of course it had a rich experience—and from this study Mr. Anthony Drexel found a basis for organizing the Drexel Institute of Technology, which in effect has inherited on a very large scale the early responsibilities and achievements of The Franklin Institute itself.

After an interval we find the Institute back in the field of combustion. It studied the smoke nuisance in Philadelphia and evolved a combustion code which, they tell me, served the City well until it had to be suspended during World War I. Up the same alley was its study of the prevention of fires in theatres at a time when those catastrophes made the headlines all too often.

The principal contribution of Franklin Institute to the first World War was a wireless telegraphers' school for draftees.

THE CENTENARY AND AFTER

I think you will agree that when 1924 rolled around the Franklin Institute could look back on 100 years of real and ramified service to the community and to the world. As a matter of fact, the Centennial ceremonies, which covered three days, attracted 800 delegates from all parts of the world, including the largest group of Nobel prize winners ever gathered together.

When, as would be natural, the Board of Managers took stock of where the Institute then stood and where it was going, what they saw was not all good. Philadelphia and its industry, and in fact the progress of the mechanic arts, had utterly outgrown the old quarters on Seventh Street. More serious, though, was the fact that when in 1923 the School of Mechanical Drawing had been shut down, there remained no activity of the Institute to link it day by day with the people of Philadelphia as a whole, and particularly the youth of Philadelphia. The Board of Managers saw that a new deal was in order and they tackled the job with the same energy and vision which their predecessors had shown a hundred years before. They enlisted the services of Dean McClenahan of Princeton (formerly Professor of Physics there), as Secretary of the Institute. They joined forces with the Poor Richard Club to build a living, functioning memorial to Benjamin Franklin—an idea originally sprung by one of our present Managers, Mort Gibbons-Neff, who was then President of the Poor Richard Club. Mr. Cyrus H. K. Curtis became the President and was a tower of strength in putting the project over. In an extraordinary money-raising campaign, under the chairmanship of Senator Pepper, over $5,000,000 was raised from 11,000 subscribers in twelve days. On land granted by the City of Philadelphia the building we are in now was built between 1930 and 1934. When the Institute moved into this great building an old

dream came true—a great scientific and industrial museum, well-arranged, well-operated, and open to the public—serving with the heroic statue of Dr. Franklin by James Earle Frazer as a fitting memorial to him.

MUSEUM

Those of you who have been through the Museum from top to bottom, know that it covers just about the whole front of pure and applied science. Its basic sections cover Physics, Chemistry, and Mechanics; there are sections devoted to Transportation on land, at sea and in the air. There is a music section with its fascinating offshoot —the lecture recitals on Winter Sundays. Benjamin Franklin himself is given practical honor in two sections—the section on Electrical Communications, and the one which covers Graphic Arts, where there is a complete printing establishment on view in action. Perhaps the most perfect of all the sections for its purpose is Mr. Samuel Fels' Planetarium, which speaks for itself in spreading the magic of the heavens before every visitor.

Entirely aside from the permanent sections, there is an endless round of special shows, four of them being launched this very day: two under the auspices of the Electrical Association of Philadelphia and the Bell Telephone Company, a special exhibit of new instruments by the United States Navy, and a new collection of "firsts" in the Franklin Hall and the Hall of Honor. Those of you who saw them today know that everyone should do likewise.

The Museum has well fulfilled its function and purpose. Something like 300,000 people visit it every year. At some time during his course every school child in Philadelphia is given a chance to go through the Institute under expert guidance, and they come back again and again and again.

LIBRARY

Some time ago I talked about the Library in the early days of the Institute. In its new quarters—called Pepper Hall for obvious reasons —it has come into its own as one of the great scientific libraries of the world. It is the best Patent library in the United States outside of New York and Washington. Ever since that very first year I told you about, it has been exchanging and receiving publications of the principal scientific and technical societies here and abroad, and it is housing them in a way that makes them accessible when you want obscure information and want it badly. A few of the rare and precious possessions are:

Experiments and observations on electricity made at Philadelphia by Benjamin Franklin. 1751.
De Revolutionibus, by Nicolaus Copernicus. 1543.
Dialogo, by Galileo Galilei. 1632.
Philosophiæ naturalis principia mathematica, by Isaac Newton. 1714.
History and present state of electricity, by Joseph Priestley. 1767.

De re metallica, by Georgius Agricola. 1561.
Experimenta nova (ut vocantur) Magdeburgica de vacuo spatio, by Ottonis de Guericke. 1672.
Natural magick, by John Baptista Porta. 1658.
The Charters of the Province of Pensilvania and City of Philadelphia. Printed and sold by B. Franklin. 1742.

I have made spot-checks on Mr. Pertuch's library once or twice. I picked a subject at random and asked to see what the library had on it. What was produced was absolutely astonishing!

RESEARCH

I now come to a last, but by no means least, activity of the Institute. Back at the beginning of this talk I mentioned the ambition of the original Board of Managers to start a scientific workshop and laboratory. Nothing significant developed on this for just about a hundred years. The first research work undertaken on a big scale was the result of Mr. Henry W. Bartol's legacy. The Bartol Research Foundation chose to deal with fundamental problems of electricity, chiefly in the field of nuclear physics and particularly cosmic rays. This activity is carried on in a special building at Swarthmore.

A second important research job being done under the trusteeship of The Franklin Institute is the investigations in cell growth and reproduction by the Biochemical Research Foundation in Newark, Delaware.

You can well see that when World War II broke out, our Institute had a nucleus of men who had the background, and it had the will, to jump in with a helping hand on essential rush research for the United States Government under the fine scientific leadership of Dr. Allen, a metallurgical engineer, who had taken over from Dean McClenahan when he died in 1935. The Institute took on a number of development and research projects for both the Army and Navy. The extent and value of that work, which was largely of a highly secret character, will perhaps never be known to you and me and the man on the street, but we can get some indication of its importance when we remember that Admiral Hussey, head of the Naval Bureau of Ordnance, came here in person to deliver the Naval Ordnance Development award to the Institute, and Lieutenant-General Campbell, Chief of Ordnance of the Army, did likewise when presenting the Army Ordnance Distinguished Service Award.

LABORATORIES

The Institute's striking success in this work led Dr. Allen in 1942 to have the idea of conducting permanent research laboratories at The Franklin Institute, as a *quid-pro-quo* service to private industry and to the Government. Encouraged by President Redding and under the expert guidance of a committee of our Managers headed by Dr. Clamer, the laboratories were formally launched in 1945. Parts of the labora-

tories are tucked away in this building, and others housed in a building facing on North 21st Street, where you and I used to expiate our traffic tickets, and which is now a beehive of research activity.

A hundred years ago, even fifty years ago, invention and development could be and usually were one-man shows. Today the complexity of knowledge demands the cooperation of many minds, skills and techniques, and The Franklin Institute Laboratories for Research and Development, as they are called, are built around that fact. Their field is development and the associated fundamental research in engineering and the physical sciences. Underlying their varied activities is a consistent approach to the problems presented to them. First, the fundamentals involved in the problem are completely and conclusively sought out. Then by use of the data thus gathered, a theoretical solution is first worked out and followed by design, testing and sometimes construction of the apparatus or equipment or facilities sought by the research project. This is a far cry from the commoner trial-and-error method of developing new equipment and methods; in fact, our laboratory is the *least empirical* place I have seen since I escaped from college laboratories. This fundamental approach is made possible by task forces of contrasting types of specialists—physicists or mathematicians work with engineers or designers, backed by forces of specialist draftsmen, with the follow-through in the hands of builders, assemblers and testing experts. Serving such groups also are extensive shop facilities, for in the basement of this building there is quite a shop which produces a wide range of components in wood, plastics and metal. Under our own roof are the facilities for making and assembling, on the one hand, the tiny parts required for delicate special instruments, and on the other hand, for building machines of substantial size.

I want to tell you a little about some of the things the Laboratory staff is doing along these lines. One general field is the fundamental and practical study of the electrical and mechanical properties of solid materials—and are those people thorough! By the time they are through with their electron microscopes which magnify up to 200,000 times, with their hardness testers, their ultramicrotomes to cross-examine some poor, innocent, defenseless material on the inner secrets of its behavior, it has absolutely no personal privacy left!

One particular example is a project aimed at taming that unpredictable substance, synthetic rubber. To this end a synthetic rubber latex is subjected to all sorts of indignities. One of these involves shaking it in one direction at frequencies higher than those of sound waves, and passing a beam of light through the latex solution at the same time in another direction. By observing how much the light rays are deflected by the shimmy of the vibrating latex, our physicists can tell how elastic the latex is.

These physicists use language which either has not been discovered

by the dictionaries or is considered by them not fit to print. In fact, the Laboratories have a brochure which I am sure was written by Lewis Carroll; for instance, "Gyros are useful in indicating and maintaining a relative horizontal irrespective of the angular position of the mounting of the gimbols," or as Mr. Carroll said in an earlier book:

> "'Twas brillig and the slithy toves
> Did gyre and gimble on the waves."

Another example of fundamental study of the properties of materials is a job the Laboratories are doing in connection with that old riddle: "What is the coefficient of friction?" When I was in college and we used to pester our physics instructors for a definite answer on just what is friction, they used to get evasive and tell us that it was a ratio between one thing and another. The Laboratories are working on a very important aspect of "What is friction?"; that is, what goes on when two metals are rubbed together at very high speeds such as are needed in the latest aeronautical engines and centrifuges? For this the Laboratories have a machine in which one revolving piece of metal is picking on another at the gentle cruising speed of 1360 miles an hour. I might add that this unit was put in a pit underground so that if anything happens on that experiment and something lets go, William Penn won't be knocked off the top of City Hall.

Illustrating the task-force approach, a theoretical physicist is working on this project with mechanical and electrical engineers and with technicians, designers and skilled instrument makers.

Up the same alley as that project is another one to develop a reliable and scientific means for determining the hardness of abrasive wheels. Up to now, this has been done by a horse-and-buggy method. The Institute made use of the fact that this hardness is in direct proportion to the modulus of elasticity of the wheel, and devised a neat instrument for measuring it.

An offshoot of these material-testing activities involves fundamental research on the combustion of liquid and gas fuels. The Institute has a battery of instruments for this job, including spectrometers and photometers, and it even uses television. In effect, the Laboratories are televising the agonies of oil while it is being burned at the stake.

This science of testing and observing the behavior of materials reaches a climax when the Laboratories develop what they call "simulators." A simulator is an electro-mechanical brain which fakes all of the practical operating conditions which a machine must successfully withstand. This simulator stunt is being used for testing the behavior of airplanes in flight by subjecting them, right in this building, to the same conditions that they will encounter in actual flight, and by observing the results in comfort on instruments. Before the days of simulators, millions of dollars and several years would be devoted to

designing and building a test airplane which was sent aloft on its first trip with a prayer. The simulator cuts most of that out.

When it comes to converting all this fundamental testing into actual instruments and machines, the Laboratories are doing important work in several fields. One is the design and construction of advanced measurement and control equipment. For instance, it designs and produces what are known as servomechanisms—more light-fingered than the most expert magician, or more infallible than the most dependable of men. These servomechanisms can do control jobs which are beyond the dexterity of a human being; in other cases they eliminate the human element when that is necessary. Also, the Laboratories are active in designing special mechanized computing machines, and are applying new principles to the design of magnetic recorders. They are in the forefront of developments in electrical communication, such as microwave high-frequency transmission, coaxial cable, television, telemetering, and remote radar guidance and control.

In carrying through to a successful conclusion their thorough approach to machine design, the Laboratories make free use of modern methods to predetermine the strength of component parts, including photoelastic tests and strain gauges.

Topping off this welter of up-to-the minute activities in promoting the mechanic arts, the Laboratories are operating a small industrial Hollywood in which their experience, talent and production connections are used to turn out good sound motion pictures for telling stories about processes, procedures or devices.

There are now about 300 people on the Laboratory staff and the extent of their activities, measured in terms of simoleons, is now at the rate of about $1,800,000 per year.

THE FUTURE

Together, we have had a good look at The Franklin Institute of the past and of the present. Pride in the past is all very well so far as it goes. But in thus looking back, let us make sure to use what we see, in charting a course for the future. The first thing that stands out is, that the Philadelphians of 125–150 years ago were an up-and-coming, keen, energetic crowd. Inspired by Franklin's example and exhilarated by their still-fresh Americanism, they tackled civic needs and industrial opportunities with a bang. They started factories; they founded hospitals, schools, colleges, scientific societies and cultural groups; financed them successfully; and made them click so well that they largely survive to this day. Thanks to them, the Philadelphia of those days was a progressive city—ahead of the times in many ways—known far and wide for its accomplishments.

Can we say that this is still so? How are we Philadelphians today doing by comparison with the old-timers of 1825? Our much-revered

ancestors had only horses and buggies then, and we have gasoline now; in keeping up with their example, *hadn't we better step on it?*

What more can The Franklin Institute contribute to the Greater Philadelphia of the future? I offer you and our able President, Mr. Nalle, four semi-detached thoughts, and suggest that you decide as we go whether Ben Franklin (if he were here tonight) would vote "Yes" or "No" on each.

First, let us recapture the Institute's early successes in getting on top of its financial destiny. Too many of our city's "non-profit" institutions take that title too literally. Deficits and decay go hand in hand. If we receive State or City aid, let it be as producers, not as paupers.

Second, let us resume one of our long-dormant activities; that is, the objective investigation of public problems. In this complex era, our City and State need expert scientific help in settling many new questions that are beyond the scope of their regular staffs. The time is ripe for our City and State Governments to look to The Franklin Institute and other great local learned bodies for research, as the Federal Government is already doing.

Third, the Franklin and other Institutes can help industry by providing a fountain at which mature workers can quench their thirst for knowledge. Industry wants its employees to grow, to make themselves more valuable, and thus to get ahead; it wants to promote from within. Many of its good workers are handicapped by scanty education, some of its executives are hampered by having only a specialized training. There is a need for places where 30-, 35-, 40-year olds can go to get practical training in industrial sciences and techniques.

My *fourth* and *last* notion is a vague, illusivė thing—yet no less a challenge to our desire to serve. Let us take our cue for this one from a last look at the scientists of 1825. In those days they wrapped up the sciences— physics, chemistry, electricity, mathematics, biology, political economy—into one package which they called Natural Philosophy, and they tried thus to see the significance of the new wonders to the gallant realm of the spirit—to the human welfare, to the freedoms, to the moralities, to what they called natural law. Their elation over the new knowledge had *warmth* and an awareness of its meaning to the progress of mankind.

By contrast, science is now intensely abstruse, specialized, exact, absolute. To achieve eminence there, men and women must work for years in cloistered isolation, with test tubes, instruments, and mathematical equations as their closest companions. As they rise higher in this rarefied atmosphere, it is easy to lose a sense of proportion and the human touch, and to take on the arrogance of an aristocratic caste in new form. Expose that frame of mind to work on the destructive power of the newly discovered natural forces, and you have a sinister

mixture with explosive possibilities of which we already are all too well aware.

I propose that The Franklin Institute interest itself dynamically in helping to keep science and scientists human, ethical, American, and thus geared to the well-being of mankind and not to its torture, enslavement, or destruction. I will not offer a diagram of how this can be done; it probably involves reviving the Natural Philosophy package and idea in a 1950 form, called perhaps Philoscience, or maybe—if the Institute really takes hold of it—Phillyscience. In any case, there is a place for a Marquis of Queensbury spirit in helping Science to "keep it clean." If our fine old Institute can somehow take hold of this as it so well has done for its many other achievements, its future usefulness and eminence are assured.

DEFLECTION OF BEAMS BY THE OPERATIONAL METHOD

BY

WILLIAM T. THOMSON[1]

INTRODUCTION

It is not commonly known that the operational method of Laplace transformation offers the simplest approach to the beam problem. In contrast to the classical method which requires equations to be written for each interval between concentrated loads, the operational method enables one to account for any loading by a single equation in terms of boundary values at the origin. Beams with abrupt changes in cross section offer no unusual difficulties to the operational method.

THE OPERATIONAL METHOD

The operational method is based on the Laplace transform which is defined as follows:

$$\int_0^\infty f(x)e^{-sx}dx = F(s), \tag{1}$$

where $f(x)$ is said to be Laplace transformed to $F(s)$ and abbreviated as $\mathfrak{L}f(x) = F(s)$. Thus the evaluation of the transforms of various functions is a matter of performing the operation indicated in Eq. 1 which in most cases involves nothing further than integration by parts. For instance, the transform of a derivative $\frac{dy}{dx} = f'(x)$ is

$$\int_0^\infty f'(x)e^{-sx}dx = f(x)e^{-sx}\Big]_0^\infty + s\int_0^\infty f(x)e^{-sx}dx$$

$$= -f(0) + sF(s).$$

The inverse transformation of $F(s)$ to $f(x)$, abbreviated as $\mathfrak{L}^{-1}F(s) = f(x)$, is in general a more difficult operation and $F(s)$ must in many cases be reduced by partial fractions or expansion to forms recognized as resulting from the first operation indicated by Eq. 1. Thus the transform of x is

$$\int_0^\infty xe^{-sx}dx = -\frac{xe^{-sx}}{s}\Big]_0^\infty + \frac{1}{s}\int_0^\infty e^{-sx}dx = \frac{1}{s^2}$$

and the inverse transformation of $\frac{1}{s^2}$ is x. For those familiar with complex variables, the Fourier-Mellin inversion integral and the theory of residues offer the simplest approach to the evaluation of the inversion.

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THE BEAM EQUATION

The differential equation for the loading of a beam is

$$EI\frac{d^4y}{dx^4} = f(x), \tag{2}$$

where $f(x)$ represents the loading, considered positive in the upward direction. The transform of Eq. 2 is

$$EI\{s^4Y(s) - s^3y(0) - s^2y'(0) - sy''(0) - y'''(0)\} = F(s)$$

which on rearranging becomes

$$Y(s) = \frac{y(0)}{s} + \frac{y'(0)}{s^2} + \frac{y''(0)}{s^3} + \frac{y'''(0)}{s^4} + \frac{1}{EI}\frac{F(s)}{s^4}. \tag{3}$$

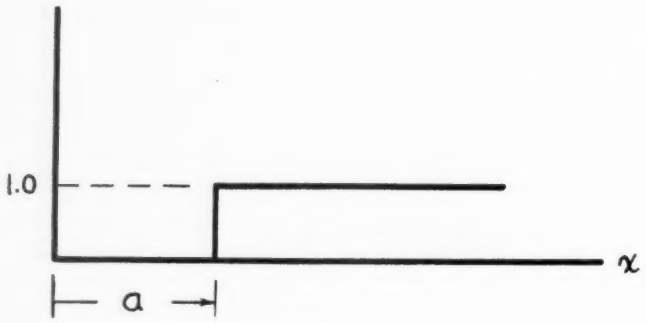

FIG. 1.

The deflection $y(x)$ is the inverse of Eq. 3 which is

$$y(x) = y(0) + y'(0)x + y''(0)\frac{x^2}{2!} + y'''(0)\frac{x^3}{3!} + \frac{1}{EI}\mathfrak{L}^{-1}\frac{F(s)}{s^4}. \tag{4}$$

In the above equation, the boundary values at $x = 0$ are identified as

$$\begin{aligned} y(0) &= \text{deflection at } x = 0, \\ y'(0) &= \text{slope at } x = 0, \\ y''(0) &= \frac{1}{EI}M(0) = \frac{1}{EI} \times \text{moment at } x = 0, \\ y'''(0) &= \frac{1}{EI}V(0) = \frac{1}{EI} \times \text{shear at } x = 0. \end{aligned} \tag{5}$$

In general, some of these quantities are known. The remaining unknown quantities at $x = 0$ are then evaluated from the known deflection, slope, moment, or shear at some other point along the beam.

THE LOAD FUNCTION

Before evaluating the boundary values at $x = 0$, the load function $f(x)$ and its transform $F(s)$ must be known and the following operational concepts are necessary.

(1) Unit Function

The unit function $u(x - a)$ is used to represent uniformly distributed loads. It is also the basic building block for other functions. As shown in Fig. 1, it is equal to unity for x, greater than "a" and zero everywhere else. The transform of such a function is

$$\mathfrak{L}u(x - a) = \int_0^a 0 \cdot e^{-sx}dx + \int_a^\infty 1 \cdot e^{-sx}dx = \frac{e^{-as}}{s}. \tag{6}$$

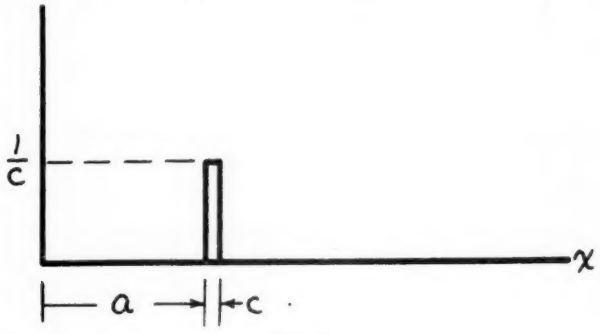

FIG. 2.

(2) Unit Impulse

The unit impulse $u_i(x - a)$, shown in Fig. 2, is used to represent concentrated loads. It is defined by the limit

$$u_i(x - a) = \lim_{c \to 0} \frac{u(x - a) - u(x - a - c)}{c} \tag{7}$$

with the added restriction that $\int_0^\infty u_i(x - a)dx = 1.0$. Its transform can be obtained by substituting the transform of each term in Eq. 7 and using L'Hospital's rule.

$$\mathfrak{L}u_i(x - a) = \lim_{c \to 0} \frac{e^{-as} - e^{-(a+c)s}}{cs} = e^{-as}. \tag{8}$$

(3) Unit Doublet

The unit doublet $u_d(x - a)$, shown in Fig. 3, is used to represent concentrated moments. It is defined by the limit

$$u_d(x - a) = \lim_{c \to 0} \frac{u(x - a) - 2u(x - a - c) + u(x - a - 2c)}{c^2}. \tag{9}$$

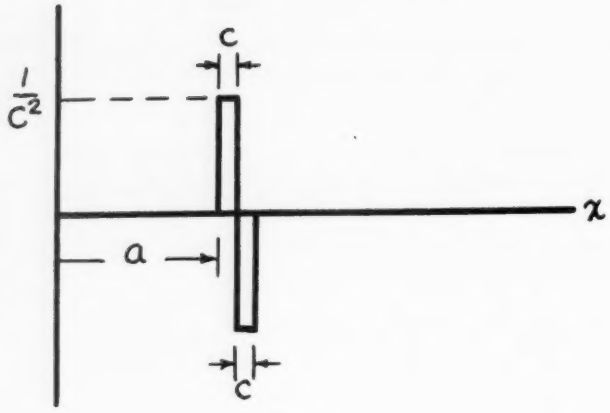

FIG. 3.

For determining its transform we use the same procedure as for the unit impulse, the indeterminate form after two applications of L'Hospital's rule becoming

$$\mathfrak{L}u_d(x-a) = \lim_{c\to 0} \frac{e^{-as} - 2e^{-(a+c)s} + e^{-(a+2c)s}}{c^2 s} = se^{-as}. \qquad (10)$$

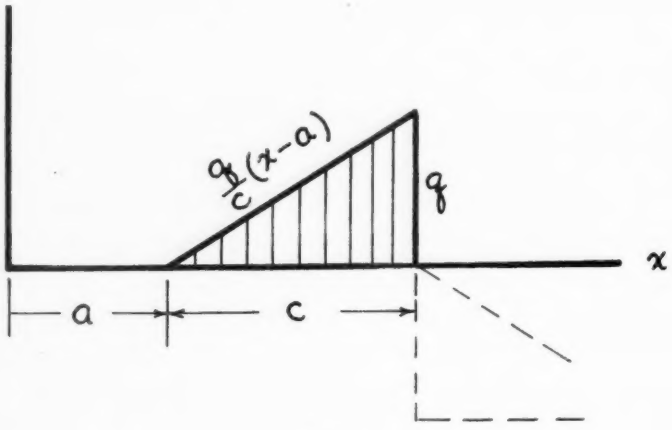

FIG. 4.

(4) *Uniformly Increasing Load*

Figure 4 represents a uniformly increasing load over the interval $x = a$ to $x = a + c$. The load function $f(x)$ for such loads can be

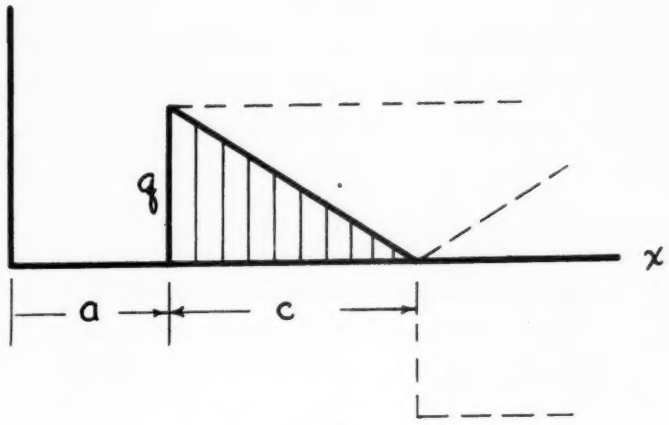

FIG. 5.

written as

$$f(x) = \frac{q}{c}(x-a)u(x-a) - qu(x-a-c) - \frac{q}{c}(x-a-c)u(x-a-c), \quad (11)$$

and its transform is

$$F(s) = \frac{q}{c}\frac{e^{-as}}{s^2} - q\frac{e^{-(a+c)s}}{s} - \frac{q}{c}\frac{e^{-(a+c)s}}{s^2}. \quad (12)$$

If the load is turned around as in Fig. 5, the load function and its transform become

$$f(x) = \left\{ q - \frac{q}{c}(x-a) \right\} u(x-a) + \frac{q}{c}(x-a-c)u(x-a-c), \quad (13)$$

$$F(s) = q\frac{e^{-as}}{s} - \frac{q}{c}\frac{e^{-as}}{s^2} + \frac{q}{c}\frac{e^{-(a+c)s}}{s^2}. \quad (14)$$

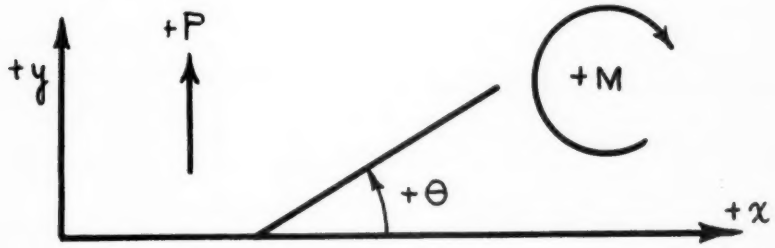

FIG. 6.

APPLICATIONS

The sign convention adopted is indicated by Fig. 6. The problem resolves into one of writing down the quantity $\mathfrak{L}^{-1}\frac{F(s)}{s^4}$ and evaluating the unknown quantities at $x = 0$ from known values at some other point.

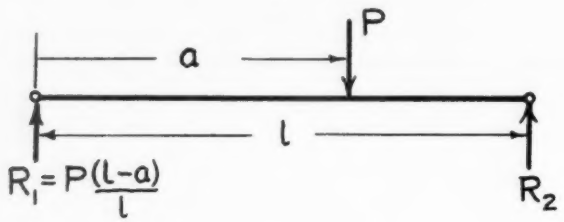

FIG. 7.

Example 1

Figure 7 shows a simply supported beam with a concentrated load at a. Its load function, transform, and contribution to the deflection are respectively

$$\begin{aligned} f(x) &= -Pu_i(x-a), \\ F(s) &= -Pe^{-as}, \\ \mathfrak{L}^{-1}\frac{F(s)}{s^4} &= -P\frac{(x-a)^3}{3!}u(x-a). \end{aligned}$$

Substituting into Eq. 4, with $y(0) = y''(0) = 0$ and $y'''(0) = \frac{R_1}{EI}$,

$$y(x) = y'(0)x + R_1\frac{x^3}{3!EI} - \frac{P}{3!EI}(x-a)^3u(x-a).$$

From the boundary condition $y(l) = 0$ we obtain

$$y'(0) = -\frac{R_1l^2}{3!EI} + \frac{P}{3!EI}\frac{(l-a)^3}{l}$$

and the final equation becomes

$$y(x) = \left\{\frac{-R_1l^3 + P(l-a)^3}{3!EIl}\right\}x + R_1\frac{x^3}{3!EI} - \frac{P(x-a)^3}{3!EI}u(x-a).$$

Since $u(x-a) = 0$ for $x < a$ and 1.0 for $x > a$ the last term is retained only for the right side of the beam.

Example 2

For the moment M applied at "a" as in Fig. 8, we have

$$f(x) = -Mu_d(x-a),$$
$$F(s) = -Mse^{-as},$$
$$\mathfrak{L}^{-1}\frac{F(s)}{s^4} = -M\frac{(x-a)^2}{2!}u(x-a).$$

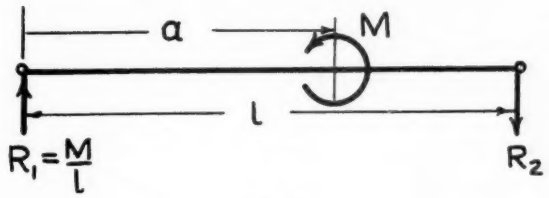

FIG. 8.

The boundary condition $y(l) = 0$ results in

$$y'(0) = -\frac{R_1 l^2}{3!EI} + \frac{M(l-a)^2}{2!EIl}$$

and the final equation becomes

$$y(x) = \left\{ -\frac{R_1 l^2}{3!EI} + \frac{M(l-a)^2}{2!EIl} \right\} x + R_1\frac{x^3}{3!EI} - M\frac{(x-a)^2}{2!EI}u(x-a).$$

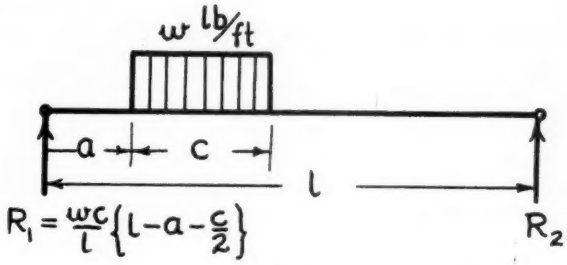

FIG. 9.

Example 3

For the uniform loading shown in Fig. 9, we obtain

$$f(x) = -w\{u(x-a) - u(x-a-c)\},$$
$$F(s) = -\frac{w}{s}\{e^{-as} - e^{-(a+c)s}\},$$
$$\mathfrak{L}^{-1}\frac{F(s)}{s^4} = -\frac{w}{4!}\{(x-a)^4u(x-a) - (x-a-c)^4u(x-a-c)\}.$$

Substituting into Eq. 4 and using the boundary condition $y(l) = 0$, we obtain

$$y'(0) = -R_1 \frac{l^2}{3!EI} + \frac{w}{4!EIl}\{(l-a)^4 - (l-a-c)^4\},$$

$$y(x) = \left\{ -R_1 \frac{l^2}{3!EI} + \frac{w}{4!EIl}[(l-a)^4 - (l-a-c)^4] \right\} x + R_1 \frac{x^3}{3!EI}$$

$$- \frac{w}{4!EI}\{(x-a)^4 u(x-a) - (x-a-c)^4 u(x-a-c)\}.$$

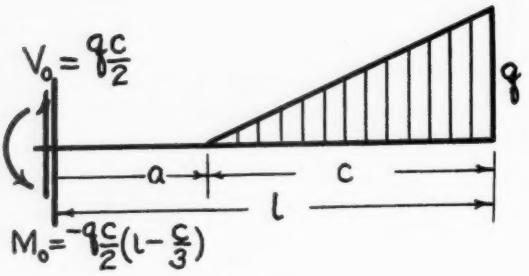

FIG. 10.

Example 4

For the cantilever of Fig. 10, we have from Eq. 12

$$\mathcal{L}^{-1}\frac{F(s)}{s^4} = -\frac{q}{c}\frac{(x-a)^5}{5!}u(x-a).$$

All the boundary values at $x = 0$ are known in this case and the deflection can be written directly as

$$y(x) = -\frac{qc}{2EI}\left(l - \frac{c}{3}\right)\frac{x^2}{2!} + \frac{qc}{2EI}\frac{x^3}{3!} - \frac{q}{5!cEI}(x-a)^5 u(x-a).$$

Example 5

Figure 11(*a*) shows a beam with an abrupt change in section at "*a*", loaded by a uniform load of w lb. per ft. It is possible to reduce this beam to one of uniform stiffness EI, with the modified loading shown in Fig. 11(*b*). To determine the modified load, we can write the following $\frac{M}{I}$ equation for the right portion of the beam with "*a*" as reference.

$$\frac{M_{x'}}{I_2} = \frac{M_a}{I_2} + \frac{V_a x'}{I_2} - \frac{w x'^2}{2I_2}$$

$$= \frac{1}{I_1}\left[M_a + V_a x' - \frac{w x'^2}{2} - M_a\left(1 - \frac{I_1}{I_2}\right) - V_a\left(1 - \frac{I_1}{I_2}\right) x' + w\left(1 - \frac{I_1}{I_2}\right)\frac{x'^2}{2}\right].$$

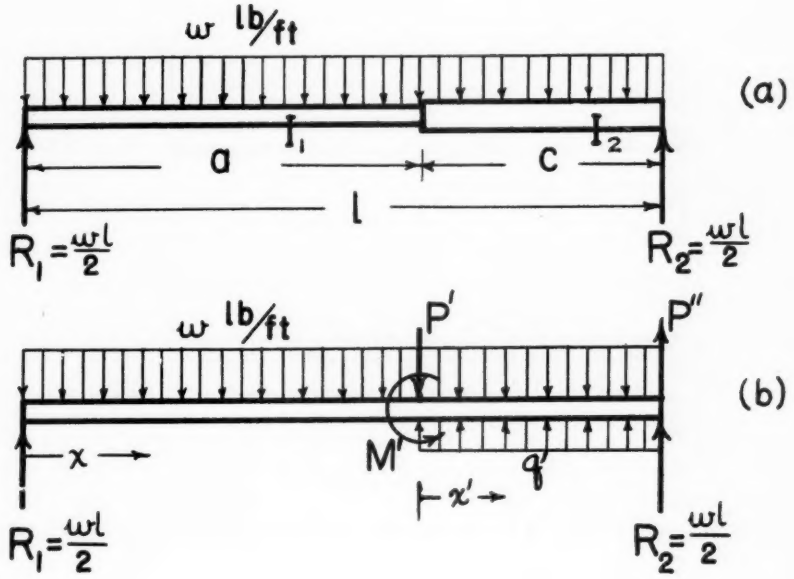

FIG. 11.

It is evident from this equation that the modified loads given by the last three terms of the above equation are

$$M' = M_a\left(1 - \frac{I_1}{I_2}\right),$$

$$P' = V_a\left(1 - \frac{I_1}{I_2}\right),$$

$$q' = w\left(1 - \frac{I_1}{I_2}\right),$$

$$P'' = V_b\left(1 - \frac{I_1}{I_2}\right).$$

The operational equations for the load thus become

$$f(x) = -wu(x) + q'u(x-a) - P'u_i(x-a) - M'u_d(x-a),$$

$$F(s) = -\frac{w}{s} + q'\frac{e^{-as}}{s} - P'e^{-as} - M'se^{-as},$$

$$\mathcal{L}^{-1}\frac{F(s)}{s^4} = -\frac{wx^4}{4!} + \left\{ q'\frac{(x-a)^4}{4!} - \frac{P'(x-a)^3}{3!} - M'\frac{(x-a)^2}{2!} \right\} u(x-a).$$

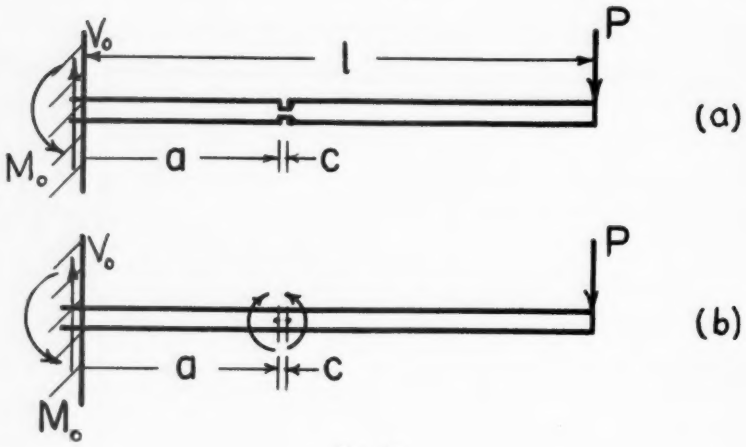

FIG. 12.

Substituting into Eq. 4 and using the boundary equation $y(l) = 0$,

$$y'(0) = -\frac{R_1 l^2}{3!EI_1} + \frac{wl^3}{4!EI_1} - \frac{1}{lEI_1}\left\{ q'\frac{(l-a)^4}{4!} - \frac{P'(l-a)^3}{3!} - \frac{M'(l-a)^2}{2!} \right\},$$

$$y(x) = \frac{1}{EI_1}\left\{ -\frac{R_1 l^2}{3!} + \frac{wl^3}{4!} - \frac{q'(l-a)^4}{4!l} + \frac{P'(l-a)^3}{3!l} + \frac{M'(l-a)^2}{2!l} \right\} x + R_1\frac{x^3}{3!EI_1} - \frac{wx^4}{4!EI_1} + \frac{1}{EI_1}\left\{ q'\frac{(x-a)^4}{4!} - \frac{P'(x-a)^3}{3!} - M'\frac{(x-a)^2}{2!} \right\} u(x-a).$$

Example 6

Figure 12(*a*) shows a beam with a narrow slot at $x = a$. The $\frac{M}{I}$ equation indicates that such beams can be reduced to a uniform beam

with a doublet $M' = M_a\left(\frac{I}{I_c} - 1\right)$ at $x = a$ and $(a + c)$ as shown in Fig. 12(b). Regardless of the type of loading, the contribution of the slot to the deflection becomes

$$f(x) = M_a\left(\frac{I}{I_c} - 1\right)\{u_d(x - a) - u_d(x - a - c)\},$$

$$F(s) = M_a\left(\frac{I}{I_c} - 1\right)\{se^{-as} - se^{-(a+c)s}\},$$

$$\mathfrak{L}^{-1}\frac{F(s)}{s^4} = M_a\left(\frac{I}{I_c} - 1\right)\left\{\frac{(x - a)^2}{2!}u(x - a) - \frac{(x - a - c)^2}{2!}u(x - a - c)\right\}$$

$$\cong M_a\left(\frac{I}{I_c} - 1\right)c(x - a)u(x - a).$$

For a cantilever beam with a load P at the end, $M_a = -P(l - a)$ and the deflection becomes

$$y(x) = -\frac{Pl}{2!EI}x^2 + \frac{P}{3!EI}x^3 - \frac{P(l - a)}{EI}\left(\frac{I}{I_c} - 1\right)c(x - a)u(x - a).$$

For a simply supported beam with a load P at midspan, the deflection becomes

$$y(x) = \left\{-\frac{Pl^2}{16EI} - \frac{M_a}{EIl}\left(\frac{I}{I_c} - 1\right)c(l - a)\right\}x + \frac{P}{3!EI}\left\{\frac{x^3}{2} - \left(x - \frac{l}{2}\right)^3 u\left(x - \frac{l}{2}\right)\right\} + \frac{M_a}{EI}\left(\frac{I}{I_c} - 1\right)c(x - a)u(x - a),$$

where $M_a = \frac{Pa}{2}$ or $\frac{P(l - a)}{2}$, depending on whether the slot appears to the left or right of the load P.

CONCLUSION

With a very limited knowledge of the operational method, the statical deflection of beams can be determined in a very simple manner. The general expression for the deflection (Eq. 4) corresponds to the Maclaurin expansion mentioned by Hetenyi (1); however, the opera-

tional scheme results in a more definite interpretation of the load. Deflection for the more complicated loading can be determined by the superposition of simple cases such as those of Examples 1, 2, and 3. The method can be extended to indeterminate and continuous beams.

BIBLIOGRAPHY

(1) M. HETENYI, "Deflection of Beams of Varying Cross Section," *Jour. Appl'd Mech.*, Vol. 4, No. 2, pp. A49–52 (June, 1937).

(2) W. THOMSON, "The Laplace Transform Solution of Beams," *Jour. Acoustical Soc. Am.*, January, 1949.

(3) W. THOMSON, "Vibration of Slender Bars with Discontinuities in Stiffness," ASME Paper No. 48–A17. Presented at Annual Conv. of ASME, Dec., 1948.

(4) M. F. GARDNER AND J. L. BARNES, "Transients in Linear Systems," Vol. 1, New York, John Wiley & Sons, Inc., 1942.

(5) RUEL VANCE CHURCHILL, "Modern Operational Mathematics in Engineering," New York, McGraw-Hill Book Co., 1944.

(6) HORATIO S. CARSLAW AND J. C. JAEGER, "Operational Methods in Applied Mathematics," London, Oxford University Press, 1947.

ANALYSIS OF A VARNISH USED BY STRADIVARIUS

BY

JOSEPH MICHELMAN[1]

The writer (1)[2] recently proposed that the old Italian violin-makers Stradivarius, Amati, Guarnerius, etc., employed the metal rosinates in compounding their famous varnishes. For instance, it was shown that aluminum and iron rosinates might have been used to produce the various shades of brown varnishes. Aluminum rosinate "dyed" with madder extract could have been used to prepare the orange-colored varnishes. If the old Italian masters employed these metal rosinates, then the metal elements should be present today despite the passage of the two hundred to four hundred years since the "lost art" flourished in Italy between the years 1550 and 1750. These elements would be detectable in the analytical spectrograph which fortunately requires very small amounts of material, as specimens of varnish from these old instruments are extremely difficult to obtain.

Analyses of ten specimens of brown varnish (2) and of one specimen of brown-red varnish (3) have already been published. These analyses were confirmatory and disclosed that the metal elements that were predicted should be present were present. In addition, some unexpected elements (impurities) were revealed which shed more light on the composition and the origin of the raw materials used by the old Italians.

It is the purpose of this article to report the analysis of the varnish on an authentic Stradivarius instrument—the Prince Gurski Strad cello made in 1697. The varnish sample was submitted by Frederick E. Haenel, Gaylordsville, Conn., a well-known connoisseur of old Italian instruments. The varnish was received "on the wood" in a good state of preservation; it was light brown in color and very transparent. It is believed that this is the first time that the varnish used by Stradivarius has been subjected to microchemical and spectrographic analyses. As the name and fame of Antonius Stradivarius (1644–1737) have been raised to a pinnacle not approached by any other violin-makers of ancient or modern times, the results of these analyses should be informative and interesting.

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

MICROCHEMICAL TEST

The "dust" scrapings of a small area of the specimen were ashed in a 1 ml. crucible and the residue dissolved in 2 drops of 5 per cent hydrochloric acid, using gentle heat. After cooling and adding 1 drop of 1 per cent potassium ferrocyanide solution, a decided blue coloration was obtained. A blank test was made simultaneously using only the reagents.

As it has been proposed (1, p. 40) that the transparent brown color of the old Italian varnish is due to the presence of solubilized iron compounds and as it has been proved that the presence of iron rosinate in varnishes will produce a marked browning effect, then the presence of iron in this varnish specimen may be considered confirmatory. Conversely, the absence of iron would have completely disproved the proposal that the old Italian violin-makers used the metal rosinates in their varnishes.

It should be mentioned that this test is applicable to varnishes with some reservations as many modern varnishes contain iron pigments which might give the same reaction. However, the transparency of the varnish in this instance attested to its genuineness; the presence of pigments would have imparted opacity. It is noteworthy that the varnishes on some modern violins tested for iron did not give the ferrocyanide reaction. The wood of these instruments had been stained, and the varnish was devoid of any coloring matter. It may not be premature to state that: if the brown varnish on a violin does not give the ferrocyanide reaction for iron, it is not old Italian varnish. This reaction may have some value in determining the authenticity of questionable old instruments.

SPECTROGRAPHIC ANALYSIS

Goldblatt (4) reported the following results from a "ten-fold-range" spectrographic analysis of this specimen of Stradivarius varnish.

Al, Si	each present 0.08 to 0.8%
Ca	present 0.03 to 0.3%
Fe, Mg, Na	each present 0.01 to 0.1%
Pb	present 0.008 to 0.08%
Cu, Ag, Sn, B	each present 0.005 to 0.05%
Cr, Ni, K, Ti	not detected

These findings are in complete agreement with the previous analyses of the old Italian brown varnishes. The explanation for the presence of the various elements, previously published, will apply fully to this analysis. The "impurities" owe their origin to the ores and the mine waters from which the ancients prepared their raw materials, especially their mineral salts and solutions.

The amounts of the metal elements reported in the foregoing analysis may appear small and require some explanation for this reason.

Upon further consideration and calculation, it will be found that they are present in the proper proportions. To illustrate this point, aluminum will be assumed to represent the total of the metal elements present. It has been shown (1, p. 50) that aluminum tri-rosinate is formed by precipitation methods; the content of Al in this compound is less than 3 per cent. A varnish formulation of three parts raw linseed oil and two parts of aluminum rosinate has been suggested (1, p. 56) as a suitable varnish for violins. The Al content in this varnish would then be reduced to about 1.2 per cent, which approximates the total of all the metal elements reported by analysis.

The small amount of iron present in the analysis may also require explanation, especially since the brown color of the varnish is due to the presence of compounds of this element. Early in the investigation of the metal rosinates as constituents of the old Italian varnish, it was learned that if iron rosinate was the only resin in a linseed oil varnish, the varnish film upon exposure to sunlight eventually became very deep brown, almost black. Thereupon quantitative studies (1, p. 44) were made using aluminum rosinate (colorless) in varying amounts as a diluent for the iron rosinate (brown) in oil varnishes. It was determined that if the ratio of iron to aluminum in combined rosinates was as low as one part of iron to nineteen parts of aluminum in such varnishes, a tan-brown color was obtained upon exposure to sunlight for several months. As the browning effect produced by the iron increases with time and as the varnish on this Stradivarius cello is over two hundred and fifty years old, the effect of the presence of a small amount of iron on the color is understandable.

Of the six principal elements present in the analysis, iron is the only one capable of producing a pronounced brown color in oil varnishes *per se*. The rosinates of these other elements yield practically colorless films. Accordingly, aluminum rosinate might be considered as representative of the rosinates of the other principal elements, and the quantitative data obtained using aluminum rosinate as the color-diluent should be applicable to a mixture of these metal rosinates.

It is now hoped that, because of these encouraging results in analyzing the varnishes of the old Italian masters, more owners of these instruments will contribute specimens for further research in solving this age-old problem.

REFERENCES

(1) JOSEPH MICHELMAN, "Violin Varnish," Cincinnati, Ohio (1946).
(2) JOSEPH MICHELMAN, *American Paint Journal*, Feb. 16, 1948, p. 62.
(3) JOSEPH MICHELMAN, *Science*, June 25, 1948, p. 679.
(4) ALAN GOLDBLATT, Chicago Spectro Service Lab., Inc. priv. comm.

Plastic Paint Coating (*Paper Trade Journal*, Vol. 128, No. 10).—Corrosion resistant plastic coatings have been developed especially for the pulp and paper industry for the protection and maintenance of chemical processing equipment. Described as an inexpensive, easily applied, high solids synthetic paint, the coating is said to be unsurpassed in protecting metals, wood and ceramic surfaces against chemical attack by corrosive fumes, condensates, spillage, etc., and to dry quickly by solvent evaporation to an adhesive, hard-wearing, flexible, glossy coating without the necessity of priming the surface being coated. Manufacturer states that the compounding ingredients have been selectively determined by laboratory research to provide the utmost adhesion and resistance to chemical attack without the use of conventional priming and intermediate coating procedure to achieve a corrosion resistant film for general maintenance purposes. Further to cut the cost of corrosion protection, formulations have exceptionally high solids content which result in a coating of substantial body and hiding power with coverage of 350 to 450 sq. ft. of area per gallon per coat when applied by brushing directly from container. The plastic coatings are said to be unaffected by all alkalies as well as by their salts and by most mineral acids, also to be inert to alcohols, soaps, water, oxidants, food and fruit acids, oils, aliphatic hydrocarbons, gasoline (low octane) and many other corrosive reagents. Moisture vapor transmission rate for films of 0.002 in. thickness is given as less than 2.0 grams per 100 sq. in. of area for 24 hr. at 100 per cent relative humidity. Non-oxidizing coatings are recommended by manufacturer for services to 180 F., and to maintain flexibility over a wide range of temperatures. CycLon coatings are made by Poly-Cyclo Products Co.

Two-Way Radio for Tractor Maintenance (*Electronics*, Vol. 22, No. 3).—Farmers in remote hill villages in Lanarkshire, Scotland, can have help sent to them by radio if they have trouble with their farm machinery or if they suddenly need new spare parts for their tractors.

Livewire Lanark engineer Daniel Ross has established his own radio station and a system of two-way radiotelephony between his headquarters and a fleet of five vans with which he services several hundred Ferguson tractors he has sold to farmers in the county.

To the road-licensing authorities one 14-hp. van is DVD600, but to Ross and driver Bill Boyd, it is Ross Able (its sister vans are Ross Baker, Ross Charlie, Ross Dog and Ross Easy).

Inside the vans a panel below the dashboard holds the two-switch controls. Behind the driver's seat a case some eighteen inches square houses receiver and transmitter. Range of the equipment varies from 25 to 40 miles, according to local conditions. On routine monthly service checks of tractors on farms, the receiver is switched on, a green light showing under the dashboard, and the van is parked close to the tractor being serviced. This permits the driver-operator to hear calls that come through from headquarters.

Back at headquarters, ex-Wren Jessie Young moves counters about a map of Lanarkshire as the vans report their whereabouts, and decides which van is nearest to the farmer who needs help.

Without the two-way radio equipment, a farmer might lose a whole afternoon of precious time before a van could be contacted and sent to his rescue.

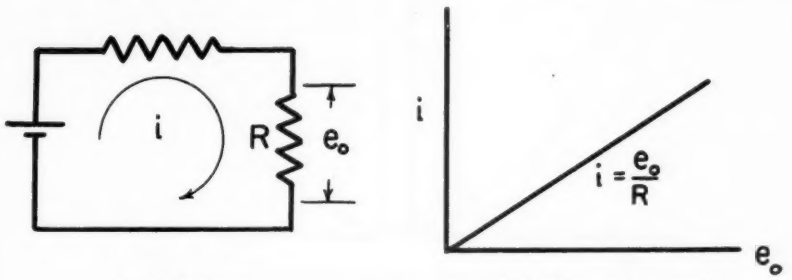
OPERATIONAL APPROACH TO NON-LINEAR CIRCUIT ANALYSIS

BY

GERALD H. COHEN[1]

1. INTRODUCTION

The simplicity of calculations involved in the solution of electric circuit problems containing linear parameters is lost when an extension of the analysis is made to include those circuit elements whose characteristics are extremely non-linear. A most obvious example of a linear circuit is a simple series resistance circuit which is characterized by a linear relationship between the current through the resistance and the voltage drop across it (Fig. 1). The expression for the current as a



(*a*) Series circuit (*b*) Resistance characteristic

FIG. 1.

function of the voltage drop is a linear function. Linear algebraic functions possess the unique property that the sum of two such functions is also a linear function. In effect, this is the principle of superposition. Simplicity results since each effect (current) may be considered additive and each cause (voltage) may then be considered separately. However, linear systems exist purely in the abstract. As a first approximation, linearity may be assumed in many cases with little noticeable error, but some electronic systems differ from the linear case and as such any assumptions of linearity do not yield credible results.

When orthodox methods are applied to the analysis of physical problems the penalty for being rigorous is complexity. In fact, in many cases this complexity causes the engineer to seek graphical solutions (1).[2] These non-analytic methods are rough and in many cases hide the actual physical reasoning and even belie the solution.

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

2. STATIC CHARACTERISTIC CURVE OF A DIODE

In the following paragraphs we shall first discuss the method for obtaining an explicit expression for the current-voltage characteristic curve of the non-linear element. The simple series electric circuit containing the diode as the non-linear element will be used to illustrate the method of analysis.

The amount of labor entailed in the treatment of non-linear circuits may be reduced by obtaining an expression of the form, $i = f(e_0)$, for the static characteristic curve (current *vs.* voltage) with a view towards ease in mathematical operation. The method used should apply to those cases for which the plotted characteristic has no explicit mathematical form and may even apply to "class B" or "class C" operation of amplifiers.

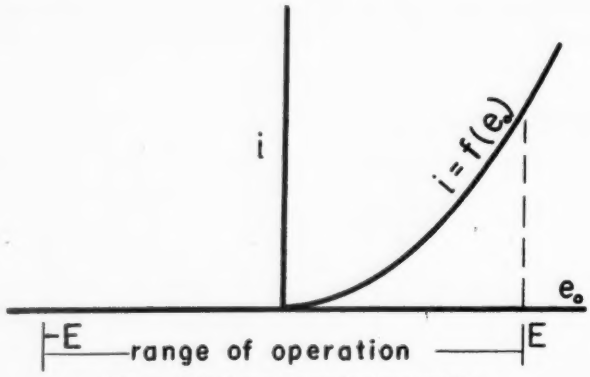

FIG. 2. Diode-rectifier static characteristic.

One of the most used treatments to obtain an explicit mathematical expression is to express the characteristic curve as a Fourier series. It is usually assumed that whenever a function is to be expressed by a Fourier series the orthogonal functions involved are either sines, cosines, or both (2). However, other orthogonal functions which are not transcendental can be used, and in particular, Legendre polynomials are quite useful. The use of orthogonal polynomials requires only that the *first* derivative of the function exists and that the function be continuous in the interval considered. Thus, where a Taylor or power series expansion is valid only where *all* derivatives exist (for example, in the conductive region of a diode), a series of orthogonal functions may be used to a greater advantage since the range of operation considered may reach into the non-conductive region. In particular, an expansion in a series of Legendre polynomials results in a more appropriate mathematical expression for the static characteristic (3) curve, and also affords the simplicity of superposition.

Let it be assumed that the complete static characteristic of a par-

ticular diode is obtained. It may be the result of published data or measurements made in the laboratory. An operating point is chosen where both the current and voltage are zero. The path of operation is considered to be between $-E$ and $+E$ (Fig. 2). A suitable change of variable is made so that the interval lies between $+1$ and -1. Then the static characteristic may be expressed to v terms as:

$$i = f(e_0) = \sum_{n=0}^{v} D_n P_n(e_0), \tag{1}$$

where the coefficients D_n may be evaluated from the expression

$$D_n = \frac{2n+1}{2} \int_{-1}^{+1} f(e_0) P_n(e_0) de_0 \tag{2}$$

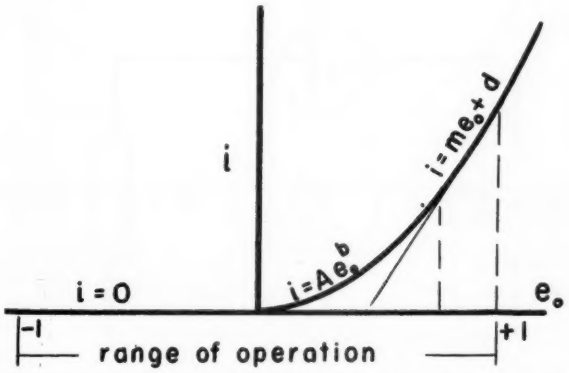

FIG. 3. Iterated curve to obtain an empirical equation for the static characteristic of Fig. 4, by means of Legendre Polynomial.

and where Legendre polynomials P_n are

$$\begin{aligned} P_0(e_0) &= 1, \\ P_1(e_0) &= e_0, \\ P_2(e_0) &= \tfrac{1}{2}(3e_0^2 - 1), \\ P_3(e_0) &= \tfrac{1}{2}(5e_0^3 - 3e_0), \\ &\cdots\cdots\cdots\cdots \\ P_n(e_0) &= \frac{1}{2^n n!} \frac{d^n}{de_0^n}(e_0^2 - 1)^n. \end{aligned} \tag{3}$$

The values of $P_n(e_0)$ for any $(-1 \leq e_0 \leq 1)$ can be obtained from a book of tables of function such as Jahnke and Emde (6). If e_0 is negative, then

$$P_n(-e_0) = (-1)^n P_n(e_0).$$

The static characteristic curve of a diode can usually be expressed as an iterated function. For example, for the plotted characteristic shown

in Fig. 3, it follows from empirical deduction (3) that

$$\begin{aligned} f(e_0) &= 0 && \text{for} \quad e_0 \leq 0, \\ f(e_0) &= Ae_0^b && \text{for} \quad 0 \leq e_0 \leq c, \\ f(e_0) &= me_0 + d && \text{for} \quad c \leq e_0 \leq 1. \end{aligned} \tag{4}$$

Then the coefficients D_n for this particular function are obtained from Eq. 2 by use of an iterated integral

$$D_n = \frac{2n+1}{2}\left[\int_{-1}^{0} 0de_0 + \int_{0}^{c} Ae_0^b P_n(e_0)de_0 + \int_{c}^{+1} (me_0 + d)P_n(e_0)de_0\right]. \tag{5}$$

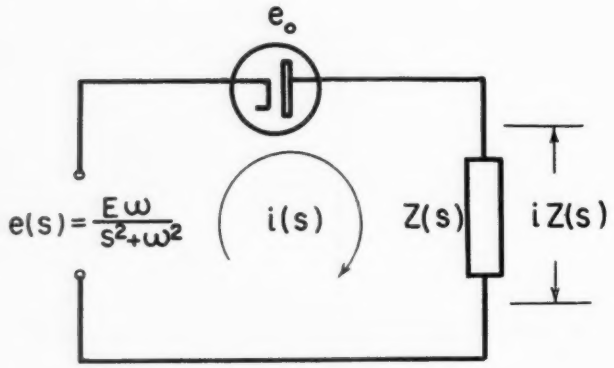

FIG. 4. Operational circuit.

The resulting expansion in Legendre polynomials may then be expanded in a finite series of powers of e_0^n where the coefficients of like powers of e_0^n are obtained from Eqs. 3 and 5. This gives as a final expression:

$$i = A_1e_0 + A_2e_0^2 + \cdots + A_ve_0^v. \tag{6}$$

3. TRANSFORM EQUATION

It is now assumed that the diode is connected in series with a known linear impedance $Z(s)$, and a harmonic driving voltage (Fig. 4). If the impedance consists of resistance only, the plate current expression can be developed from Eq. 6 by writing e_0 in terms of the impressed voltage less the drop across the resistance and solving this equation for the current. Regardless of frequency or wave-form of the current, the voltage drop across the resistance is simply the product of the current and resistance.

If the impedance, $Z(s)$, also contains reactive elements, it is not independent of frequency. When a sine wave voltage is impressed on

the circuit, the resulting diode current has an infinite number of frequency components. Thus, no simple expression for the impedance when multiplied by the current will give the voltage drop across the impedance as is the case for pure resistance (4).

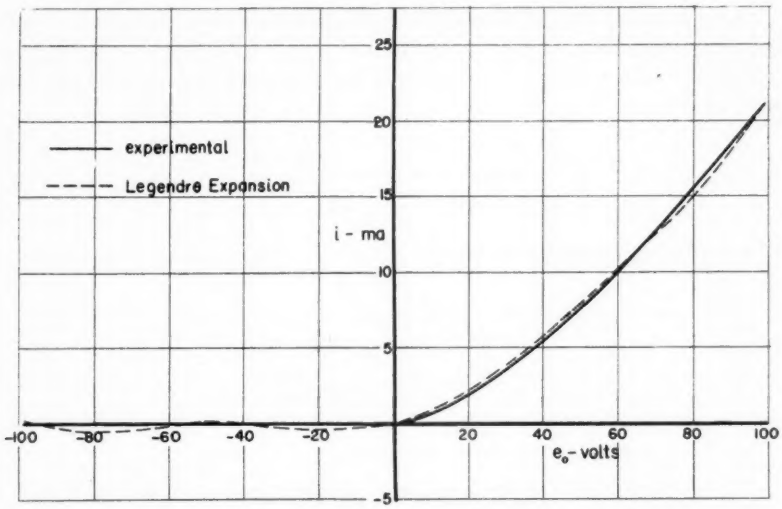

FIG. 5. Comparison of the measured characteristic curve of a typical diode to the Legendre Expansion.

For simplicity, we can make use of the operator $Z(s)$ where jw in the familiar a-c. circuit impedance functions is replaced by s (5). We also demand that all terms which contain e (the instantaneous value of the driving voltage) raised to a power be reduced to linear terms. For example, if $e^2 = E^2 \sin^2 (wt + \theta)$, then:

$$e^2 = \frac{E^2}{2}[1 - \cos (2wt + 2\theta)].$$

The voltage drop across the linear load impedance is then $iZ(s)$ and [3]

$$e_0 = e - iZ(s), \tag{7}$$

$$i = A_1(e - iZ) + A_2(e - iZ)^2 + \cdots + A_r(e - iZ)^r. \tag{8}$$

We *seek* solutions of the form

$$i = C_1e + C_2e^2 + \cdots + C_re^r, \tag{9}$$

where the current is a function of e alone and the C_i are complex oper-

[3] Wherever Z occurs, it will be tacitly assumed that $Z = Z(s)$.

ators. Equation 9 can also be written as:

$$i = i_1 + i_2 + \cdots + i_r, \tag{10}$$

where

$$i_r = C_r e^r.$$

The operators C_r can be found from Eqs. 8 and 9 by first substituting (9) in the right side of Eq. 8 and expanding. Then, equating the coefficients of like powers of e, we find for terms of order one (the first power of e):

$$C_1 = A_1 - A_1 Z C_1, \tag{11}$$

$$C_1 = \frac{A_1}{1 + A_1 Z},$$

and for the higher order terms

$$C_2 = \frac{A_2}{(1 + A_1 Z)^3},$$

$$C_3 = \frac{A_3(1 + A_1 Z) - 2A_2^2 Z}{(1 + A_1 Z)^5}, \tag{12}$$

etc.

We have already referred to the operator $Z(s)$; in reality, this is a symbolic representation of the Laplace transformation of the impedance function where the initial conditions are omitted (5). The initial energy conditions will be considered here as zero, but they may be included with the transform of the driving voltage. The use of the Laplace transform throws most of the emphasis on algebraic manipulation of complex function rather than on the solution of a series of differential equations of the non-linear type which are usually not solvable by ordinary means. The Laplace operation

$$\mathfrak{L}\{f(t)\} = \int^{\infty} f(t)e^{-st}dt = f(s),$$

for a harmonic driving voltage, $e(t) = E \sin wt$, is

$$\mathfrak{L}\{e(t)\} = \frac{Ew}{s^2 + w^2},$$

$$\mathfrak{L}\{e^2(t)\} = \mathfrak{L}\left\{\frac{E^2}{2}[1 - \cos(2wt)]\right\} = \frac{E}{2s} - \frac{Ew}{s^2 + (2w)^2}, \tag{13}$$

etc.,

where, as stated previously, each power of e is reduced to linear terms; then the transform of each term is obtained. If we denote $i(s)$ as the

transform of $i(t)$, then from Eqs. 10, 11, 12, and 13

$$i_1(s) = \frac{A_1}{1 + A_1Z}\, e(s) = \frac{A_1}{1 + A_1Z} \cdot \frac{wE}{s^2 + w^2} = \frac{G_1(s)}{f_1(s)},$$

$$i_2(s) = \frac{A_2}{(1 + A_1Z)^3}\left[\frac{E}{2s} - \frac{Ew}{s^2 + (2w)^2}\right] = \frac{G_2(s)}{f_2(s)}, \tag{14}$$

. . . . . .

$$i_r(s) = \frac{G_r(s)}{f_r(s)}.$$

4. THE INVERSE TRANSFORMS

To find the current products i_r as functions of time, it is necessary to obtain the inverse transforms $\mathfrak{L}^{-1}\left\{\frac{G_r(s)}{f_r(s)}\right\}$ by use of partial fraction expansion. It is evident that the rational algebraic fraction $\frac{G_r(s)}{f_r(s)}$ has multiple order poles. Only $\frac{G_1(s)}{f_1(s)}$ has a first order pole. We will now assume that

$$1 + A_1Z = a + sb,$$

where

$$a = 1 + A_1\mathbf{R}(Z),$$
$$b = A_1\mathbf{I}(Z),$$

and $\mathbf{R}Z(s)$ and $\mathbf{I}Z(s)$ are the resistive and reactive components of $Z(s)$, used in a generalized manner as an extension of steady state a-c. circuit theory (**5**).

Expanding the expression for the first component of current transform in (14) yields:

$$i_1(s) = \frac{A_1}{a + sb} \cdot \frac{wE}{w^2 + s^2} = \frac{K_{11}}{a + sb} + \frac{K_{12}}{s + jw} + \frac{K_{13}}{s - jw},$$

where

$$K_{11} = \left[\frac{G_1(s)}{f_1'(s)}\right]_{s=-a/b} = \frac{wA_1E}{b\left(w^2 + \frac{a^2}{b^2}\right)},$$

$$K_{12} = \left[\frac{G_1(s)}{f_1'(s)}\right]_{s=-jw}, \tag{15}$$

$$K_{13} = \left[\frac{G_1(s)}{f_1'(s)}\right]_{s=jw},$$

$$f_1'(s) = \frac{d}{ds}(f_1).$$

Since the inverse transform of $\frac{1}{s+\alpha}$ is

$$\mathfrak{L}^{-1}\left\{\frac{1}{s+\alpha}\right\} = e^{-\alpha t},$$

the inverse transform of $i_1(s)$ is

$$i(t) = K_{11}e^{-at/b} + K_{12}e^{-jwt} + K_{13}e^{jwt}. \tag{16}$$

Expanding the expression for $i_2(s)$ into partial fractions

$$i_2(s) = \frac{EA_2}{2s(a+sb)^3} - \frac{EwA_2}{(a+sb)^3(s-2jw)(s+2jw)}$$

$$= \frac{K_{21}}{s} + \frac{K_{22}}{(s+a/b)^3} + \frac{K_{23}}{(s+a/b)^2} + \frac{K_{24}}{(s+a/b)} - \frac{K_{25}}{s-2jw}$$

$$- \frac{K_{26}}{(s+2jw)} - \frac{K_{27}}{(s+a/b)^3} - \frac{K_{28}}{(s+a/b)^2} - \frac{K_{29}}{(s+a/b)},$$

where

$$K_{21} = \left[\frac{EA_2}{2(a+sb)^3}\right]_{s=0} = \frac{EA_2}{2a^3},$$

$$K_{22} = \left[\frac{EA_2}{2sb^3}\right]_{s=-a/b} = -\frac{EA_2}{2b^2a},$$

$$K_{23} = \left[\frac{d}{ds}\left(\frac{EA_2}{2sb^3}\right)\right]_{s=-a/b},$$

$$K_{24} = \left[\frac{1}{2!}\frac{d^2}{ds^2}\left(\frac{EA_2}{2sb^3}\right)\right]_{s=-a/b},$$

$$K_{25} = \left[\frac{EwA_2}{(a+sb)^3(s+2jw)}\right]_{s=+2jw},$$

$$K_{26} = \left[\frac{EwA_2}{(a+sb)^3(s-2jw)}\right]_{s=-2jw},$$

$$K_{27} = \left[\frac{EwA_2}{b^3[s^2+(2w)^2]}\right]_{s=-a/b},$$

$$K_{28} = \left[\frac{d}{ds}\left(\frac{EwA_2}{b^3[s^2+(2w)^2]}\right)\right]_{s=-a/b},$$

$$K_{29} = \left[\frac{1}{2!}\frac{d^2}{ds^2}\left(\frac{EwA_2}{b^3[s^2+(2w)^2]}\right)\right]_{s=-a/b}.$$

Finding the inverse transform of $i_2(s)$ using the following relationships:

$$\mathfrak{L}^{-1}\left\{\frac{1}{s}\right\} = 1,$$

$$\mathfrak{L}^{-1}\left\{\frac{1}{(s+\alpha)^n}\right\} = \frac{t^{n-1}e^{-\alpha t})}{(n-1)!}$$

yields

$$i_2(t) = K_{21} + \left[K_{24} - K_{29} + \frac{t}{1!}(K_{23} - K_{28}) + \frac{t^2}{2!}(K_{22} - K_{27})\right]e^{-at/b} - K_{25}e^{2jwt} - K_{26}e^{-2jwt}.$$

The expressions for the rest of the current components desired may be obtained in a similar manner.

5. SUMMARY

The preceding paragraphs show that an extension of the operational method can be made to include non-linear circuit problems by first expanding the expression for the unknown variable i in a power series of the driving function e. Each term of the series represents a component of the total current. Each component is an operational expression for a *linear* differential equation involving the current component i_r to the first power, the impedance C_r corresponding to this component of current, and the driving voltage raised to the power r. The non-linearity is therefore shifted from the unknown dependent variable i to the known independent variable e, making it possible to find and solve the transformed equations for each current component.

REFERENCES

(1) A. PREISMAN, "Graphical Constructions for Vacuum Tube Circuits," McGraw-Hill Book Co., 1943.

(2) W. I. BARROW, "Contribution to the Theory of Non-Linear Circuits with Large Applied Voltages," *Proc. I.R.E.*, August, 1934.

(3) I. S. AND E. S. SOKOLNIKOFF, "Higher Mathematics for Engineers and Physicists," McGraw-Hill Book Co., 1941.

(4) K. MCILWAIN AND J. G. BRAINERD, "High Frequency Alternating Currents," Second ed., John Wiley & Sons, 1939.

(5) M. F. GARDNER AND J. L. BARNES, "Transients in Linear Systems," John Wiley & Sons, 1945.

(6) E. JAHNKE AND F. EMDE, "Tables of Functions with Formulas and Curves," Dover Publications, 1943.

Transparency Binding Made Easy with Bindomat, New Leitz Product.—The Bindomat, a new device simplifying and speeding the task of binding transparencies, has been announced by E. Leitz, Inc.

A boon to those who have fussed and fumbled with the binding of their transparencies, the new Leitz Bindomat was invented by Julius Huisgen of the Leitz staff. It is designed to permit correct mounting, convenient lining-up and rapid binding of both 35 mm. and $2\frac{1}{4}$-in. square transparencies with a minimum of handling and effort. The Bindomat is economical, too, for each slide costs only one-third as much as other types of mounting.

Prototypes of the Bindomat were tested by practical photographers for a period of several months. Their suggested modifications and improvements were incorporated in the finished product which accepts both 2 and $2\frac{7}{16}$-in. square glasses (with their appropriate masks), for 35 mm. and $2\frac{1}{4}$-in. square transparencies.

The illuminating platen in the Bindomat is used to examine and align the transparencies before mounting. It also makes a handy and excellent viewer. Twenty slots in the back of the Bindomat provide a rack in which slides mounted between glasses are placed before binding.

Binding tape is fed from a full roll at the left of the Bindomat by a fluted spindle which provides the right amount of grip on the adhesive side of the $\frac{1}{2}$-in. tape. A channel for the tape extends to $2\frac{7}{16}$-in. to accommodate the larger slides and it has an adjustable stop which may be pulled across it for binding 2-in. square slides.

The cutting knife is set at the correct cutting angle, and slightly "toed" to insure a precise cut on both cloth and plastic tape. A spring locating stop, attached to the knife spindle, swings down with the knife to hold the tape, and to center the slide before the actual cut is made.

The taped edge of the slide is then pressed down into the binding slot and pulled through rubber rollers. This action seals the tape to the glass. A short slot is provided for resting the slide while more tape is fed out. The process is repeated for the remaining three sides to completely mask and bind the slide.

The Bindomat is supplied complete with 100 Leitz ground edge, 2 × 2-in. glasses; binding tape for more than 120 slides; 100 metallized masks for 35-mm. transparencies; and a "C" clamp.

Photoflash Battery Tester.—The Bright Star Battery Company announces the introduction of its Photoflash Battery Tester. This precision instrument has been developed at the insistent demand of many dealers, news service, professionals and advanced amateurs who desired a reliable method of testing photoflash batteries.

The meter is scientifically constructed to test safely and accurately the three popular sizes of photoflash batteries under load or service conditions similar to those of actual usage in photoflash equipment. Pressure on a switch button will clearly indicate on the dial the condition of the battery for photoflash service.

Exhibited for the first time at the National Photographic Show in New York it met with enthusiastic distributor, dealer and consumer approval.

REFRACTIVE TEMPERATURE

BY

ARNOLD COURT[1]

ABSTRACT

Refraction tables used in navigation and surveying are almost all derived from those of Bessel, whose computations, based on English star observations, assume that atmospheric temperature decreases with height at the rate of about 0.6 F.° per 1,000 ft. Neither this assumption nor that of any subsequent investigator is entirely in accord with present-day knowledge of atmospheric structure, which generally has a temperature decrease of around 3 F.° per 1,000 ft. to the tropopause, with widely varying conditions above it. The Bessel tables in general use cannot be extrapolated for surface air temperatures much different from 50° F.; in particular, for extreme cold conditions it is desirable to use, in place of the actual air temperature, the *refractive temperature*, which is that temperature for which the refraction correction given in the tables equals the correction which is actually required, and which may be estimated from general climatic considerations.

INTRODUCTION

Refractive temperature, rather than actual temperature, should be used in determining the correction for atmospheric refraction for any astronomical observation for position, if this correction is to be taken from any of the tables commonly used by surveyors and navigators. The difference between these two temperatures is especially important for observations at zenith distances greater than 70° or 75°, when the actual temperature is unusually low and under certain other meteorological conditions.

As here proposed, *refractive temperature* is that temperature for which the refraction correction given in the tables equals the correction which is actually required. It applies primarily to the calculation of position observations made with theodolites, transits, and sextants, and not to the more elaborate computations of astronomers, although in such computations also the effect of weather conditions and various climatic regimes must be considered.

Actually, the temperature correction often is negligible, being usually smaller than the probable error of most navigation or azimuth observations. But since refraction tables include a temperature correction table, and use of such corrections is widespread, their basis should be known. If a temperature correction is applied to the refraction computation, it should be as accurate as possible, and therefore should be based not on the actual air temperature at the time of observation, but on the *refractive temperature*.

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In this paper, the need for refraction corrections and their magnitude are discussed, the origins and assumptions of refraction tables in current use are explained, examples are given of errors involved in use of tables under all weather conditions, and a method is suggested for approximating the *refractive temperature*. Because navigators and surveyors work chiefly in English units, such units are used here.

GENERAL

Refraction corrections must be applied to astronomical observations because light rays passing through atmospheric layers of differing densities are bent toward the denser layer. In the atmosphere, the density always decreases with height (except in the few inches above a strongly heated surface such as a pavement or roof on a hot day), but at a rate which depends primarily on the temperature distribution.

On the average, the temperature of the air grows colder at increasing heights up to the "tropopause," at 5 to 10 miles. Above the tropopause, at which the temperature is between $-50°$ F. and $-130°$ F., the temperatures decrease or increase only slightly, for another 10 miles or so, then increase rapidly to about $+160°$ F. at heights of 30 to 40 miles. Above this level temperature falls again, then rises at heights above 50 miles (**9**),[2] but at these levels the atmosphere is so rare that differences in its density have no appreciable effect on incoming light rays. The density (temperature) distribution in only the lowermost 40 miles need be considered in computing the refraction (**21**).

These, however, are average conditions. The thermal structure of the atmosphere varies widely from day to night, season to season, and place to place. The diurnal range of temperature at the surface, from afternoon heat to pre-dawn chill, diminishes rapidly with height, and is only a degree or two above 2,000 or 3,000 ft. In summer the rate of temperature decrease, known as the lapse rate, is greater than it is in winter; it is also greater in tropical regions than in high latitudes. In the tropics, the tropopause is around 10 miles up, and about $-120°$ F.; in polar regions, it remains at around 6 miles but varies from $-50°$ F. in summer to $-80°$ F. in winter, and may even vanish (**1**).

Most serious variation, from the standpoint of practical refraction computations, is the variation in the temperature distribution in the lowermost 2,000 ft. or so of the atmosphere. On any clear night the radiative cooling of the ground cools the adjacent air so that an *inversion* is created; that is, instead of the usual decrease of temperature with height, the temperature increases upward for a few hundred or thousand feet. During winter in cold continental regions, such inversions can become most pronounced. Wexler (**10**) has determined that the theoretical maximum limit to such an inversion is about 50 F.° when the surface temperature is 32° F., but is only 20 F.° when the surface temperature is $-94°$ F.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

Inversions of another sort, but equally important in the computation of atmospheric refraction, persist along seacoasts where the water is much colder than the land, and winds blow onshore. (California is an example.) Such inversions usually are at 3,000 to 5,000 ft., and may amount to as much as 20 F.° (6). Below them, the lapse rate shows the usual variation between day and night conditions, and above them a more or less "normal" lapse rate exists.

During stormy weather, the atmospheric structure may be extremely complicated, but at such times astronomical observations usually cannot be made, so the refraction computation is unimportant. Occasionally, however, during bad weather a mariner makes a hurried "shot" of the sun near sunrise or sunset; he should realize that there is strong likelihood of unusual refraction conditions rendering the results of such a sight, no matter how carefully and exactly made, less trustworthy than one in fair weather, when the atmosphere is stable and more closely approaches the conditions assumed by his refraction table.

Detailed knowledge of atmospheric structure, outlined above, is an accomplishment of only the last decade or two. Our refraction formulas and tables, however, are generally more than a century old, and while they involve some rather keen assumptions as to the atmospheric structure of western Europe, they are woefully inadequate to serve in all parts of the world in all seasons.

There is a need today for a system of refraction computation which permits corrections for various types of atmospheric structure, but none has yet appeared. Unfortunately, those who use refraction tables, the surveyors and navigators, usually are ignorant of the source and limitations of such tables; in turn, the astronomers who should provide better tables are uninformed on the latest knowledge of atmospheric structure and its variations.

Were such tables available, they could be applied on the basis of either average conditions for the locality, or of the actually observed conditions. With the increasing use of the radiosonde, in many cases the actual atmospheric structure at the time and place of the astronomical observation is known; this is particularly true of scientific exploring parties. With such more detailed information available, and improved tables, it should be possible to use observations of bodies near the horizon with far more reliability than is possible at present.[3]

[3] Since the preparation of this paper, three recent publications bearing on the subject have been noted:

"Celestial Navigation Computation Tables," Publication No. 601 of the Hydrographic Office of Japan (Tokyo, 1942), contains tables of corrections to observed altitudes described by Dr. Charles H. Smiley (*Mathematical Tables and Other Aids to Computation*, Vol. 3, No. 23, July 1948, p. 195) as unusual because "they include corrections to be applied to altitudes less than 6°; special corrections for temperature, barometric pressure, and difference between air and water temperatures are given." The brief explanation of these tables is in Japanese, and the only clue to the nature of this temperature correction for refraction is that the name of Radau appears in the text. (See p. 586 for completion of this footnote.)

BESSEL

Almost all refraction tables used by surveyors and navigators in the United States today are derived from one basic source: the work of the great Friedrich Wilhelm Bessel. Early in the 19th century he re-analyzed the many star observations made from 1750 to 1762 at the Greenwich observatory by Bradley (19), and deduced from them a formula (13) for atmospheric refraction R:

$$R = \alpha B^{A} T^{\lambda} \tan z,$$

where α, A and λ are functions of the zenith distance, z, for which he prepared tables; B is the barometirc pressure, and T is the outside air temperature.

This formula, and the revised tables computed from it (14), soon became standard, and were incorporated into handbooks (18, 34), astronomy textbooks (20), and observatory manuals (22, 24). From these sources, or Bessel's original publications, were derived the tables used by navigators (16) and surveyors (26, 30).

The only U. S. government survey agency whose refraction tables are not wholly Besselian is the Coast and Geodetic Survey (17), which used from 1898 until 1948 tables published by Hayford (28). These were obtained by the uncritical method of arithmetically averaging refraction tables given in Doolittle's Practical Astronomy, which in turn were based on Bessel's tables, with those given in the Connaissances des Temps for 1897, which "depend upon other observations and upon a different theory—that of Laplace." Use of these tables has recently been superseded by a new publication (29), whose new tables are discussed later.

Because of this general dependence on Bessel's work, its basic assumptions must be analyzed thoroughly to understand why those tables, valid as they may have been for star observations at Greenwich, are not necessarily applicable to field work in different climates. According to Chauvenet (20), Bessel's derivation assumes that

$$1 - E(T_x - T_0) = e^{-\alpha s/k},$$

where

E is the coefficient of thermal expansion of air = 0.0036438,
T_x and T_0 are the temperatures at height x and at the surface,
e is the base of natural logarithms = 2.71828,

"Corrections to be applied to the dip of the horizon when the air is . . . warmer or colder than the water" are contained, according to Smiley (*Ibid.*, No. 25, January 1949, pp. 369–71), in H. A. Goldhammer's "Nautisk Tabelsamling" (Copenhagen, J. Jørgensen & Co., 1946); however, the introduction and explanation of the 174-page tables is limited to a single page, with no indication of the source of these corrections.

A bibliographical reference has been noted to I. Ya. Tantor, "Calculation of Atmospheric Refraction During Aerological Observations," *Izvestia Akademiia Nauk SSSR*, Ser. Geog. Geofiz, Vol. 12, No. 4, but the publication has not been studied.

a is the radius of the earth = 6,372,970 meters,
$s = x/(a + x)$, and
h is an empirical constant = 227,775.7 meters.

(Values cited are those used by Bessel; more accurate determinations of E and a do not affect the computation appreciably.)

From this relation, the temperature distribution assumed by Bessel is found to be that of a lapse rate of around 0.6 F.° per 1,000 ft., decreasing very slightly with height: for the first 1,000 ft., a drop of 0.64 F.° is required; for 40 miles, the total decrease is 121 F.°, or an overall lapse rate of 0.57 F.° per 1,000 ft. This gradient is only about a fifth of that obtaining in the English troposphere, but since it does not recognize the stratosphere, the assumed distribution is colder than actual conditions at heights greater than 20 miles.

In computing his tables based on this temperature distribution, Bessel used mean conditions as pressure 29.60 in., temperature 50° F. These are still acceptable mean annual values for London (11). To compensate for surface conditions differing from these means, Bessel's formula corrects the "normal" refraction by T^{λ}, where T is the air temperature and λ varies slightly with zenith distance; it is 1.000 from the zenith down to 40°, and at greater zenith distances becomes (15):

z:	45°	50°	55°	60°	65°	70°	75°	80°	85°
λ:	1.0018	1.0023	1.0031	1.0046	1.0068	1.0111	1.0197	1.0420	1.1229

Magnitude of this adjustment may be seen from the following tabulation of the total refraction correction, for various temperatures and zenith distances, computed from Bowditch's version (16) of Bessel's tables:

Zenith Distance	Air Temperature (Fahrenheit) −10°	+20°	+50°	+80°
60°	1′54″	1′47″	1′41″	1′35″
70°	3 00	2 48	2 39	2 30
75°	4 02	3 47	3 34	3 22
80°	6 02	5 40	5 19	5 01
85°	11 21	10 34	9 52	9 16

Actually, the effect of Bessel's correction for temperature is to alter the assumed lapse rate, increasing it for warmer temperatures and decreasing it for cooler conditions, with the temperature "at the top of the atmosphere" remaining constant. In turn, this implies that in warm weather the density increases with height less rapidly than in cold weather. While such an assumption is generally in accord with meterological conditions, Bessel's quantitative expression for it is valid only for climatic conditions such as exist in the British Isles.

MODIFICATIONS

Need for improving or modernizing Bessel's refraction formula and tables has been cited by many investigators. Bessel himself arbitrarily

increased his original values, derived for England, in the ratio of 1.003282 (20) to fit them to observations at Königsberg, where the continental climate has a steeper lapse rate than the marine climate of England.

California's marine inversion makes the net lapse rate smaller than that of England (7), so that Crawford (23) found "from observations made at the Lick Observatory that, not only are Bessel's refractions too large, but that the Pulkowa refractions are also." But Crawford did not know the cause of this difference, and his proposed refraction tables are not based on meteorological data.

An improved formula for computing refraction at zenith distances greater than 75°, applicable even for zenith distances greater than 90° (that is, object below horizon) is offered by Esclangon (25), claiming it to be simpler than Radau's. It involves an exponential decrease of the index of refraction, and a lapse rate of 2.75 F.° per 1,000 ft. up to 30,000 ft., with an increasingly steep lapse rate still higher. Above 50,000 ft., Esclangon says, the correspondence between his model and observed temperatures ceases, "but these layers are of negligible importance in refraction." He does not offer tables based on his formula, which contains an exponential constant depending on temperature.

Two other systems of refraction computation, offered in recent years by Willis (33) and Garfinkel (27), profess to use modern knowledge of atmospheric structure. Actually they rely on obsolete mean pressure-temperature-height data given by Humphreys (3), which are based on 416 central European soundings made between 1900 and 1912.

Garfinkel follows the theoretical approach of Ivory in his proposed tables, which extend to zenith distances as great as 116°. His development involves a "polytropic index", defined as

$$n = (g/aR) - 1,$$

where g is the acceleration of gravity, a the lapse rate, and R the gas constant. Since the lapse rates obtained from Humphreys' tables vary from 5.6 to 5.9 C.° per km. (3.1 to 3.2 F.° per 1,000 ft.), the values of n range from 4.8 to 5.1, and a mean value of $n = 5.0$ is adopted. This corresponds to a lapse rate of 5.8 C.° per km. or 3.2 F.° per 1,000 ft., which is rather too small for the United States, although it is generally correct for western Europe.

The formula also contains an additive correction, significant ($> 1''$) only at zenith distances greater than 86°, for the existence of the stratosphere, which is assumed to be isothermal; neither the assumed temperature of the stratosphere nor the height at which it is considered to begin are apparent from the discussion. The correction is tabulated as a function of zenith distance and observer's height; for 90° zenith

distance it varies from 2 seconds of arc at the ground to 20 seconds at 10 km. (6.2 miles), the upper limit of the table.

There is also a correction for deviation of the lapse rate from its assumed value, but "in the absence of sufficient information about the daily and seasonal fluctuations of the temperature gradient, as well as its geographical distribution, this correction is rather uncertain." Fortunately it is negligible "for zenith distances of 90° or less," Garfinkel declares. One purpose of the present paper is to point out the availability of detailed knowledge of diurnal, seasonal, and geographical variations in the lapse rate, and that the effects of these variations, especially at extreme zenith distances, are far from negligible.

Willis' "system for the computation of astronomical refraction, perhaps entirely adequate to satisfy the needs of practical astronomy, without involving star-observations themselves," includes 12 tables incorporating the latest values for the variation with temperature and wave length of the refractive indices of dry air, water vapor, and carbon dioxide. He expresses Humphreys' data as a power series,

$$T/T_0 = 0.670 + 0.5925\ (p/p_0) - 0.2625\ (p/p_0)^2.$$

From Humphreys' pressure data, this series indicates a lapse rate with a maximum of more than 3 F.° per 1,000 ft. at 10,000 ft., above which it decreases steadily with height.

No method is offered to allow for wholesale departure from this lapse rate. Willis declares that "The diurnal variation of temperature (is) . . . of the order of a fraction of 1 C° at a few km." While the average *diurnal* variation may be of this order, the *day-to-day* variation is very much larger. Ratner (**8**) has shown that, for instance, at 3 km. (10,000 ft.) over Washington, D. C., a range of about 15 C.° (27 F.°) is necessary to account for 80 per cent of the temperatures observed in January, and about half that much in July. According to Willis' Table 7, "Correction for departure of local temperature from that of standard atmosphere," at a temperature of −4° F. the refraction is increased by only 0.002 seconds of arc for zenith distances of 70° and by 0.108 seconds for zenith distances of 80°. Here, however, "the local temperature is assumed to exist in a thin layer."

U.S.C.G.S.

Willis' formula for refraction has been used to compute two independent sets of refraction tables for the recently published "Manual of Geodetic Astronomy" of the Coast and Geodetic Survey (**29**). Because of the recency of this publication, and the fact that its tables are likely to be copied uncritically into other publications, the meteorological assumptions of these tables require complete discussion. In general, it may be said that just as Willis in developing the original basis for these tables did not avail himself of the latest and most com-

plete knowledge of variations in the state of the atmosphere, so the compilers of these tables did not utilize modern methods of determining meteorological variables, particularly atmospheric pressure.

Although the two sets of refraction tables are both based on Willis' formula, no discussion is given of the relative merits and differences of the two methods, nor of the types of observations for which each is best suited. The "simplified method" comprises a table for basic refraction and two tables of correction coefficients, one for departure of pressure from 760 mm. (29.921 in.), the other for departure of temperature from 10° C.(50° F.). Arguments of these tables are given in inches and degrees Fahrenheit. This arrangement is identical with the form of most of the commonly-used tables derived from Bessel's formula, but gives refractions about 2″ less at zenith distances of 80°. For zenith distances greater than 85°, the tables are computed from the Pulkowa Observatory Refraction Tables (1930), which agree with Willis' tables between 83° and 85°. Because this system has no corrections for lapse rate, but only for surface temperature, *refractive temperature* should be used.

The second method involves the use of Willis' complete formula:

$$\log_{10} R = \log_{10} \tan z + \alpha + \beta + \gamma + (\lambda - 1)(\gamma + 0.1\beta).$$

Here z is the zenith distance, α and $(\lambda - 1)$ are functions of z alone and are given in a single table, and β and γ are corrections for departures of air pressure and temperature from the assumed mean values of 750 mm. (10 mm. less than in the simplified form) and 10° C. (50° F.).

The correction for temperature, γ, is simply $\log_{10}(T/283)$, and is given in a single table, but without regard to any deviations from the west European lapse rate used by Willis. Although it is given for each degree from −30° C. to +44° C. (−22° F. to +111° F.), it probably is valid over less than half this range unless the *refractive temperature* is used.

The pressure correction, β, is unnecessarily complicated and confused, involving both instrumental corrections and physical considerations, some of them not pertinent. It is given as:

$$\beta = \beta_0 + \Delta\beta_t + \Delta\beta_g + \Delta\beta_w.$$

Here β_0 is the actual correction for deviation of air pressure from 750 mm., and the other three terms are corrections for, respectively, the temperature of the barometer, variation in gravity, and the wave length of the light used in the observation. The confusion is heightened by neglect to explain that

$$\beta_0 = \log_{10}(B + eC) - \log_{10} 750,$$

where B is the uncorrected barometer reading, 750 is the assumed normal pressure of dry air in mm., e is the atmospheric vapor pressure in mm., and C a factor varying directly with the wave length of the light used.

The correction, *eC*, "is equivalent to the correction of the refractive power because of the water vapor content of the air," Willis (33) explains. It changes the actual pressure to a sort of virtual refractive pressure, that is, the pressure of a mass of dry air which has the same refractive properties as the moist air actually prevailing. Logically, this correction should be applied to the true barometric pressure, that is, the barometer reading as corrected for scale errors, capillarity, temperature, and gravity, and not before such corrections are made.

Such corrections, $\Delta\beta_t$ and $\Delta\beta_g$, actually do not belong in this formula at all. A century ago it may have been permissible to include instrumental corrections in the same computation as physical variables, but such is no longer customary. Meteorologists have long considered that determining the atmospheric pressure includes the application of all necessary corrections to the reading of the mercurial barometer. A refraction formula should merely call for the use of true atmospheric pressure, corrected as required by standard practice as outlined in the Smithsonian Meteorological Tables (4) or observing manuals of the Weather Bureau or the Army or Navy weather services. Users of the Manual are left to their own devices to determine the vapor pressure, and barometric pressure should be treated similarly.

The table given for $\Delta\beta_t$ is inadequate anyhow, since it does not specify the type of barometer for which it applies. Fixed cistern barometers (used on shipboard and often in field work) require different corrections from those with movable cisterns, and the corrections differ again if the barometers are graduated in English or metric units, because then the zero points of the scales are different (4, 5).

Although not explained as such, the correction for gravity, $\Delta\beta_g$, is simply the logarithm of the ratio of the value of gravity at the place of observation to the value assumed in the tables. This assumed value is "for the latitude and elevation of the U. S. Naval Observatory in Washington, D. C." and is equivalent to that "at sea level in latitude 38°37′20″." No justification is offered for reducing the atmospheric pressure to a standard of gravity other than that used by meteorologists throughout the world, which is the value of gravity at sea level in latitude 45°. It would be preferable to follow current practice and compute the basic tables for this "standard gravity," and omit all corrections for gravity, as well as instrument temperature, from these tables.

The last correction to the barometer reading, $\Delta\beta_w$, has nothing to do with pressure at all, but is inserted in this computation for convenience. It merely increases or decreases the total refraction accordingly as the wave length of the light observed is shorter or longer than that of the yellow light, 0.578 microns, used in the basic computation. For violet light, the refraction is almost 2 per cent greater, and for red light about 0.4 per cent less.

All told, the new Coast and Geodetic tables are probably a slight improvement on the classical Besselian tables. But they could have been made far superior, had their compilers availed themselves of the latest knowledge concerning the structure of the atmosphere, and followed modern practice in the reduction and use of meteorological observations. As it is, they require, just as much as the Besselian tables, the use of *refractive temperature* for any computation involving atmospheric structure differing from that of western Europe.

EXAMPLES

While observers make every effort to observe bodies at small zenith distances, so as to avoid the large refraction corrections, it is often necessary in navigation and surveying, because of clouds, to obtain readings relatively close to the horizon. This is especially true of sun and moon observations in polar regions, where these bodies are quite low in the sky and, in the summer half-year, are the only ones observable. And it is precisely in polar regions that strong temperature inversions, with their abnormal temperature gradients, are most common, even in summer, rendering an accurate computation of the refraction correction highly essential.

Recently, summertime geodetic observations above the Arctic Circle (**31**) were based entirely on solar observations. The zenith distances, corrected according to standard practice (**17**), were consistently in error by an average of 5.4 seconds of arc. Since the thirteen sets of observations were well distributed in azimuth, averaging them cancelled this error, due to the refraction correction and uncertainty as to the gravity anomaly.

The authors conclude that "the point in favor of the polar regions is, of course, the fact that observations can be taken on the sun in all azimuths. The sun varies little in altitude and the atmosphere is quite uniform so that tables of refraction apply with constant precision." Actually, the taking of observations in all azimuths permits cancelling out of the relatively constant error in the refraction tables.

A wintertime example of errors arising from use of refraction corrections based on extremely low temperatures for observations at large zenith distances may be cited from the observations made at Little America III, Antarctica, by Leonard M. Berlin (**12**), cadastral engineer of the General Land Office and surveyor of the U. S. Antarctic Expedition of 1939–41.

Ten solar observations during January and February, 1940, gave the latitude as 78°29′06.5″S, with a standard deviation of 9.7″. Surface temperatures at these times ranged from 6 to 19° F., with probably only a slight inversion (observations of upper air data did not begin for several months). On 8 July, the zenith distance of Sirius at upper transit was observed as 61°49′00″, which, using the refraction correction

of 118″ computed from the tables (**28**) for the observed temperature of −10° F. and pressure of 28.85 in., gave a latitude of 78°29′07″; on the same day the zenith distance of Canopus at upper transit was 25°48′45″, giving a latitude of 78°29′06″.

On 18 July, the same zenith distance was obtained again for the upper transit of Sirius. But since the temperature during the observation was −55° F., with a pressure of 28.51 in., an extrapolated value of 130″ for the refraction correction was used, resulting in a latitude of 78°29′16″; the correction of 120″, based on a *refractive temperature* of −15° F., deduced from radiosonde ascents (**2**), yielded a latitude of 78°29′06″, exactly in agreement with previous determinations.

In this example, the error in latitude due to failure to use the *refraction temperature* is only 10 seconds of arc, or about 1,000 ft. However, the inversion in this case is far from extreme, and the zenith distance of 62° is not unusually great. Had the zenith distance of the sun at upper transit been observed on 5 September, when the surface temperature was −75° F. and the *refractive temperature* only −20° F., an error in latitude of about 100 seconds of arc, or nearly 2 miles, would have resulted from failure to use the proper *refractive temperature.*

APPROXIMATIONS

Unless a simple method for computing refraction corrections for various observed or assumed lapse rates becomes available, the present Besselian tables probably will continue in use for many years. Consequently, any rules for determining *refractive temperature,* even though crude and general, should improve materially the accuracy of observations at large zenith distances through atmospheres whose structure differs materially from that of England.

Actually, for adaptation to world-wide use, Bessel's tables require two corrections. First, the entire table should be altered for differences between the average picture of the atmosphere over the place of observation and the average British atmosphere; Bessel made such a correction for the Königsberg atmosphere in multiplying his original values by 1.003282. Second, the deviation of the atmospheric structure from the average must be expressed as some function of the actual difference of surface air temperatures.

Neither of these corrections can be developed rigorously, in view of the empirical nature of Bessel's original formula. Within the limits of necessary accuracy, however, both corrections may be combined. The following rules, based on study of individual atmospheric soundings and means for all parts of the world, is offered as a step toward improving computations:

The refractive temperature *is the same as the actual air temperature at the time of observation, except that it should not be more than 10 F.°*

less than the average temperature for the preceding 24 hr., nor 25 F.° less than the mean temperature of the month. It should never be less than 0° F. except in polar regions, where it may be one-fourth as far below 0° F. as the actual temperature.

For any one locality, a series of accurate observations at large zenith distances, well distributed in azimuth, should reveal the amount of error involved in strict use of Bessel's refraction tables, and permit deduction of more accurate rules for determining the *refractive temperature*. Such rules, of course, will best be determined by collaboration among astronomers, meteorologists, and geodesists. Only by use of the latest techniques and information of astronomy and meteorology can the geodesist hope to attain improved refraction tables which will not require such rather gross corrections as that for *refractive temperature*.

REFERENCES

Meteorological

(1) ARNOLD COURT, "Tropopause Disappearance during the Antarctic Winter," *Bulletin of the American Meteorological Society*, Vol. 23, No. 5, pp. 220–238 (May, 1942).

(2) ARNOLD COURT, "Meteorological Data for Little America III," *Monthly Weather Review*, Supplement No. 48. In press.

(3) W. J. HUMPHREYS, "Physics of the Air," New York, McGraw-Hill Book Co., 1929.

(4) CHARLES F. MARVIN, "Smithsonian Meteorological Tables," Fifth Revised Edition, Washington, 1931.

(5) W. E. KNOWLES MIDDLETON, "Meteorological Instruments," Toronto, University of Toronto Press, 1943.

(6) MORRIS NEIBURGER, "Temperature Changes during Formation and Dissipation of West Coast Stratus," U. S. Department of Commerce, Weather Bureau, Research Paper No. 19 (July, 1944).

(7) BENJAMIN RATNER, "Upper Air Average Values of Temperature, Pressure, and Relative Humidity over the United States and Alaska," U. S. Department of Commerce, Weather Bureau, May, 1945.

(8) BENJAMIN RATNER, "Temperature Frequencies in the Upper Air," U. S. Department of Commerce, Weather Bureau, January, 1946.

(9) CALVIN N. WARFIELD, "Tentative Tables for the Properties of the Upper Atmosphere," National Advisory Committee for Aeronautics, Technical Note No. 1200. January 1947. (Extensive list of recent papers on temperature, etc., at extreme heights.)

(10) HARRY WEXLER, "Cooling in the Lower Atmosphere and the Structure of Polar Continental Air," *Monthly Weather Review*, Vol. 64, No. 4, p. 127 (April, 1936).

(11) (Anon.) "Temperature of the Upper Air over England," British Air Ministry, Meteorological Office, 1941.

Refraction

(12) LEONARD BERLIN, "Astronomical Observations at West Base, U.S. Antarctic Service," MS in National Archives.

(13) FRIEDRICH WILHELM BESSEL, "Fundamenta Astronomiae pro anno MDCCLV deducta ex observationibus viri incomparabilis James Bradley in Specula Astronomica Grenovicensi per annus 1750–62 institutis," Königsberg, 1818.

(14) FRIEDRICH WILHELM BESSEL, "Tabulae Regiomontanae reductionum observationum astronomicarum ab anno 1750 usque ad annum 1850 computatae," Königsberg, 1830.

(15) FRIEDRICH WILHELM BESSEL, "Astronomische Untersuchungen," Vol. I, Königsberg, 1841.

(16) NATHANIEL BOWDITCH, "The American Practical Navigator," Washington, 1938.
(17) WILLIAM BOWIE, "Determination of Time, Longitude, Latitude, and Azimuth," Special Publication No. 14, U. S. Department of Commerce, Coast and Geodetic Survey, 1931.
(18) KARL BREMIKER, "Vega's Tables of Logarithms," 40th ed., Berlin, 1856. (Also 40th ed., translated by W. L. F. Fisher, Berlin, London, and New York, 1859.)
(19) C. BRUHNS, "Die Astronomische Strahlenbrechung in ihrer historischen Entwickelung dargestellt," Leipzig, 1861.
(20) WILLIAM CHAUVENET, "A Manual of Spherical and Practical Astronomy," Philadelphia, 1863.
(21) ARNOLD COURT, "Insolation in the Polar Atmosphere," JOURNAL FRANKLIN INSTITUTE, Vol. 235, No. 2, pp. 169–78 (Feb., 1943).
(22) P. H. COWELL, "Refraction Tables Arranged for Use at the Royal Observatory," Greenwich Observations, Appendix I, 1898.
(23) RUSSELL TRACY CRAWFORD, "On Astronomical Refraction," Publications of the Lick Observatory, Vol. VII, part 6. Sacramento, 1915.
(24) J. R. EASTMAN, "Refraction Tables," U. S. Naval Observatory. Washington, 1887.
(25) ERNEST ESCLANGON, "Sur la refraction astronomique," *Comptes Rendues*, Vol. 216, No. 2, pp. 100–103 (11 January, 1943).
(26) SAMUEL STINSON GANNETT, "Geographical Tables and Formulas," U. S. Department of the Interior, Geological Survey, Bull. 650, Washington, 1908.
(27) BORIS GARFINKEL, "An Investigation in the Theory of Astronomical Refraction," *The Astronomical Journal*, Vol. 50, pp. 169–79 (February, 1944).
(28) JOHN F. HAYFORD, "A Text-Book of Geodetic Astronomy," New York, 1898.
(29) ALBERT J. HOSKINSON AND J. A. DUERKSEN, "Manual of Geodetic Astronomy," U. S. Department of Commerce, Coast and Geodetic Survey, Special Publication No. 237. Washington, 1947.
(30) ARTHUR D. KIDDER, "Standard Field Tables and Trigonometric Formulas," U. S. Department of the Interior, General Land Office, Washington, 1942.
(31) G. LEIFSON AND W. T. THERRELL, "Geographical Positions by Solar Observation," *Trans. American Geophysical Union*, Vol. 28, No. 5, pp. 680–682 (October, 1947).
(32) SIMON NEWCOMB, "A Compendium of Spherical Astronomy," New York, 1906.
(33) JOHN E. WILLIS, "A Determination of Astronomical Refraction from Physical Data," *Trans. American Geophysical Union*, part II, pp. 324–338 (1941).
(34) R. S. WOODWARD, "Smithsonian Geographical Tables," Washington, 1894.

Fighting Turf Diseases (*Dupont Magazine*, Vol. 43, No. 2).—Next time you fail to sink a long putt deflected from the cup by a dead spot on the green, hold your temper until you have counted to ten. Then, if you must swear, put all the venom you please in these words, "Rhizoctonia solani!" That's the technical name of the fungus responsible for one of the turf diseases that attack fine grasses and cause these dead spots.

Your golf companions are presumably familiar with Brown Patch, Dollar Spot, and Snow Mold—three fungus disease that attack fine turf and are best known by these common names.

Brown Patch appears suddenly as discolored areas ranging from small spots to patches several feet in diameter with a dark ring or "smoke screen" around the border where the disease is still active.

Dollar Spot shows up as bleached brown spots of dead grass, and they are seldom larger than a silver dollar, although they be numerous enough to destroy large areas of turf.

Snow Mold develops in circular patches of dirty white—sometimes with a pinkish cast—and they often run together, covering large areas. This mold thrives at temperatures just above freezing, in the saturated atmosphere near melting snow or where snow covers unfrozen ground.

The once-difficult job of keeping greens has been made easier through the use of these Du Pont chemical compounds: "Tersan" organic nonmercurial fungicide, and Special "Semesan" mercurial fungicide, are effective against all three diseases as preventives or curatives. Greenkeepers whose major problems are Brown Patch or Snow Mold usually prefer "Tersan," although Special "Semesan" is their choice for a one-shot treatment. When the main problem is to control Dollar Spot, they usually select Du Pont F-531.

Use of these fungicides has reduced the prevalence of turf diseases, just as the use of Du Pont 2, 4-D and "Ammate" weed killers has controlled noxious weeds, brush, and poison ivy. Greenkeepers now have the chemical tools to make your leisure hours on the golf grounds and other recreational areas more enjoyable.

Dust Collector (*Modern Plastics*, Vol. 26, No. 8).—A small portable dust collector, Model 335 Dustkop, designed for continuous dust collecting work on production operations is being produced by Aget-Petroit Co. A self-clearing paddle wheel powered by a ¼-hp., 3450 rpm. motor picks up dust-laden air from the source of dust. After passing through the fan, dust is diverted over the surface of the dust collecting tray which consists of a series of baffles for separating out the lint, chips, and heavier dusts. Before air is returned to the working space, it goes through a filter of non-inflammable spun glass. This filter forms the top of the collector. Measuring 12 by 14 by 18 in., the collector can quickly be placed where desired and connected to a machine by means of a flexible hose.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS*

MECHANICAL PROPERTIES OF HUMAN BONES

Recent developments in highspeed aircraft subject personnel to unusual shocks and impacts in ordinary flight as well as in accidents. This has made it important to develop safety devices for protection of the human body and to establish logical criteria for the design of these devices. When it was realized that investigation of the problem involved close cooperation between the engineering and medical professions, the National Bureau of Standards was requested by the Naval Medical Research Institute to assist with the mechanical problems.

Because the human skeleton provides support for the body and protection for the vital organs, Bureau scientists decided to begin a study of the mechanical properties of human bones and joints. Results are to be used in the design of simplified mechanical models of the human frame that will make it possible to estimate the forces set up in the body during impacts of various types. Preliminary data indicate that bone may be considered an elastic, brittle material, having about one-fourth the compressive strength of cast iron and more than twice that of hickory wood.

The study was initiated with measurements of the mechanical properties of the structural members of the skeleton, beginning with long bones, and was designed to establish average values on a statistical basis. The initial work involved 17 tests on specimens made from bone of the compact type removed from near the middle of the bones of the extremities of humans and monkeys. Fourteen of these tests were made in compression with the direction of the load parallel to the fibers of the bone. One was made in compression with the direction of the load perpendicular to the bone fibers, one in bending, and another under torsion load. Test specimens consisted of sections removed from the bones and of portions machined into plates and hollow cylinders.

The results of the tests showed the average ultimate strength of the 14 compression specimens to be about 23,000 psi. The fifteenth specimen, in which the load was applied at right angles to the bone fibers, had about the same ultimate strength, indicating that the effect of the direction of loading on the bone is small. The strength of the bone in bending, that is, extreme fiber stress at failure, was slightly lower than the strength in compression. The computed ultimate shear stress for the torsion to failure was about 15 per cent of the compressive strength.

* Communicated by the Director.

SPIRAL CONTRACTOMETER MEASURES STRESS IN ELECTRODEPOSITS

The spiral contractometer, a new instrument developed at the National Bureau of Standards, conveniently and accurately measures stress in electrodeposits. Excessive stress, usually the result of the chemical nature of the plating solution or of impurities in the deposit, may cause peeling, blistering, or cracking of the coating, thus rendering the base metal more susceptible to corrosion. It may also induce failures due to stress corrosion and usually tends to decrease the fatigue resistance of the plated article.

The new instrument measures compression or tension in a specimen coating deposited on a standard helix. The stress is immediately read from a dial as the helix changes curvature in response to the forces acting within the plated layer. The device is rugged and self-contained, requires no auxiliary apparatus, and is well adapted to both industrial process control and laboratory research.

Stress determinations made with the spiral contractometer on nickel deposits are reproducible to within ± 10 per cent. Values obtained with the device are in good agreement with reported values and with measurements made by procedures based on other principles. The length of strip which may be conveniently used as a helix is four to eight times that usually found in the straight-strip instruments. This gives greater deflection for a given change in curvature, and this deflection can be magnified to any desired degree by the gear system of the instrument. In additon to the greater sensitivity thus attained, the contractometer is easily calibrated, thus simplifying calculations and eliminating errors due to variation in the physical properties of the helix. As determinations are made at the plating temperature, thermal errors are avoided. The use of a coiled strip also greatly reduces and eliminates errors caused by transverse bending.

LOW-TEMPERATURE PROPERTIES OF 18:8 STEEL

One phase of a general research program at the National Bureau of Standards concerning the influence of temperature on the mechanical properties of metals and alloys deals with the mechanical properties of austenitic 18:8 chromium-nickel steels at low temperatures ranging down to $-188°$ C. Such information adds to fundamental knowledge of these materials and is also useful in predicting their behavior when subjected to the severe conditions encountered in high-altitude flying, arctic regions, and specialized refrigeration applications.

Steels of 18:8 chromium-nickel composition, both with and without additions of molybdenum, titanium, and columbium, were included in the Bureau's investigation, which involved tests of the steels in annealed and cold-drawn conditions. A ferritic 18:8 steel of the precipitation-hardening type was also included in the study.

The tests show that the hardening and strengthening of 18:8 steels at low temperatures depend greatly upon the amount of prior plastic deformation (cold-working) the steel had received at room temperature. The increase in strength is greatest for the annealed steel and falls off with increase in the amount of prior plastic deformation at room temperature.

The metastable austenitic steels have good ductility. Even at temperatures as low as that of liquid air, the ductility, as determined by reduction of area, is about as great as at room temperature. In this respect they are similar to nonferrous metals having a face-centered cubic structure, which retain good ductility at low temperatures. The ductility of the metastable austenitic steels that have been previously subjected to plastic deformation is affected less by temperature than that of the annealed steels, as the amount of austenite transforming to ferrite in the tests at low temperature is less.

For the ferritic precipitation-hardening 18:8 steel, ductility decreases rapidly with decrease in temperature. At liquid-air temperature the steel is brittle. This 18:8 steel is similar therefore to the other ferritic steels, which lose ductility at low temperature and generally become brittle in tension tests at liquid-air temperatures.

THE FRANKLIN INSTITUTE

MINUTES OF STATED MEETING OF THE FRANKLIN INSTITUTE

Wednesday, May 18, 1949

The May Stated Meeting of The Franklin Institute was held in the Lecture Hall at 8:15 p.m. on May 18, 1949. Approximately 125 persons were present to hear the sixth Annual Charles Day Lecture.

The President of the Institute opened the short business session of the meeting by announcing that the minutes of the Stated Monthly meeting for April had been printed in full in the May Issue of the JOURNAL OF THE FRANKLIN INSTITUTE and that they carried an error. The entry to be corrected was stated to appear in Line 5 of paragraph 4, page 513, where the phrase "first world war" should be changed to "second world war." No other corrections were noted and the minutes were approved as corrected.

The Secretary reported the following members elected during the month of April, with a total at the end of that current month of 5421.

Active	47
Associate	31
Student	14

The President gave a resume of the annual report of the Board of Managers for 1948, which reports the condition of the affairs of the Institute as required by Article V, Section 2, of the By-Laws. The full report will be printed in the July issue of the JOURNAL.

Before presenting the speaker of the evening the President spoke briefly about Mr. Charles Day, in whose honor this Lectureship was founded, and about his family who made it possible.

Mr. Dale Purves then delivered the Charles Day Lecture. He chose as his subject "The Substance of Management." Mr. Purves was formerly Vice-President and General Manager of La Consolidada, S. A., of Mexico and is presently a member of the firm of Edward N. Hay and Associates, Management Consultants in Philadelphia. An interesting and informative presentation of the precepts of management in the field of engineering was given, with examples of their application, and the importance of management in that field was emphasized. Mr. Purves explained what management should accomplish and gave a comparison between scientific industrial management in Mexico and in the United States. The Charles Day Lecture will be printed in full in a subsequent issue of the JOURNAL.

HENRY B. ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, May 11, 1949.)

HALL OF THE COMMITTEE,
PHILADELPHIA, MAY 11, 1949.

MR. W. LAURENCE LEPAGE in the Chair

The following reports were presented for final action:

No. 3205: Clamer Medal.

This report recommended the award of the Francis J. Clamer Medal to William Hume-Rothery, of Oxford, England, "In recognition of his brilliant work in scientifically determining and interpreting the structure and behavior of metallic equilibrium systems."

No. 3206: Levy Medal.

This report recommended the award of the Louis Edward Levy Medal to Alan Stewart FitzGerald, of Los Angeles, California, "In consideration of his papers on the subject of Magnetic Amplifiers, appearing in the October, November, and December 1947 issues of the Journal of The Franklin Institute."

No. 3207: Ballantine Medal.

This report recommended the award of the Stuart Ballantine Medal to Sergei A. Schelkunoff, of New York, New York, "In consideration of his outstanding contributions to the extension of electromagnetic wave theory, particularly his mathematically-based concepts so helpful to the radio engineer."

JOHN FRAZER,
Secretary to Committee.

MEMBERSHIP

ACTIVE MEMBERS ELECTED AT THE MEETING OF THE BOARD OF MANAGERS, MAY 18, 1949

ACTIVE FAMILY

John P. Kelly — Albert S. Orr — Listervelt S. Winfree, M.D.

ACTIVE

John C. Achenbach
Max Black
Richard W. Blizard, M.D.
Paul N. Bookmyer
Morris W. Brody, M.D.
John J. Burns, M.D.
Vincent G. Bush
Harold W. Butler
Victor Domann
Milton M. Cahn, M.D.
Albert E. Caillat
J. Woodrow Clark, M.D.
Isadore S. Cohen, M.D.
William C. DeSieghardt
William A. Faison, Jr.
Carl Falkenstein
Joseph R. Forrest
Frank W. Hankins
James W. Harrison
George H. Jones
William H. Jordan
Meyer M. Katz
Norman Kaufman
Norman A. Mackenzie
Louis E. Malina
James A. Mehaffey
S. Creadick Rhoads, M.D.
Meier Sadowsky
John A. Schramm
Irving Scott
Owen F. Shaver
Scott P. Verrei, M.D.
E. Lloyd Watkins, M.D.
Lennard L. Weber, M.D.

ACTIVE NON-RESIDENT

Robert A. Leary — Eugene F. Murphy, Ph.D. — Frank Wenner, Ph.D., D.Sc.

NECROLOGY

Henry E. Baton '36 — Jacob Martin '42 — J. Howard Reber '38
Carl Kirsch '43 — Arthur V. Morton '28 — Edward B. Temple '07

MUSEUM

From time to time The Franklin Institute has been made the custodian of valuable apparatus or mementoes of great scientists other than Benjamin Franklin. These have now been gathered together and displayed in the Hall of Honor, adjoining Franklin Hall, where it is hoped they will serve as a source of inspiration for visitors.

The oldest in point of time is Priestley's air pump, showing the progress that had been made with this useful appliance during the first hundred years after its invention. This particular pump was made in England, since very few scientific instruments were made in this country at that time, but it was used by Priestley during his residence in Northumberland, Pa. Michael Faraday is represented by some specimens of heavy glass and coils used in his experiments on the rotation of the plane of polarization of light produced by a magnetic field.

The first machine for testing the strength of materials is also shown. This was constructed under the supervision of members of The Franklin Institute in 1832 by Super and Chapman for the investigation into steam boiler explosions. Thomas Edison is represented by two exhibits. The earliest is a recording on tin foil made by the inventor himself when applying for his first patent for the talking machine. The Commissioner of Patents (Carl Schurz) when asked to make a short speech to be recorded was resolved not to be made the victim of any deceit. He spoke in French, firmly believing that the machine could not be expected to translate his words. The other Edison memento is the first three wire generating system installed at Sunbury, Pa., in 1883. The capacity of the generators was four hundred 16 candle power lamps. The Armington Simms steam engine which provided power to the generators is attached.

The more modern phases of discovery which have penetrated deeply into our everyday life are represented by one of Sir Ambrose Fleming's original "valves," parent of all radio tubes, and specimens of Lee de Forest's "Audion" tube in which the grid was first introduced and made possible the amplification of electrical oscillations. Finally, some of the tubes used by Vladimer Zworykin in his early television experiments are displayed. These show the early types of iconoscope.

It is hoped that this collection will be augmented by gifts of similar scientific treasures.

Everyone who has visited a large museum is aware of the physical fatigue which insidiously creeps over the visitor. Pressure upon the space available has hitherto prevented the provision of a comfortable visitors' lounge in our Museum. Now that situation has been remedied. Comfortable seats in a pleasantly decorated nook now afford visitors an opportunity to rest and relax (with television entertainment when programs are available). The walls give an adequate pictorial representation of the work performed by The Franklin Institute Laboratories for Research and Development. This pleasant corner of the Museum is a tribute to the scientific workers of the laboratories and it is of the nature that will bring their labors more prominently before the public.

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in the JOURNAL within the next few months:

DE KONING, TH.: Vaporization Cooling of Large Electrical Machines.

DEJUHASZ, K. J.: Graphical Analysis of Impact Bars Stressed Above the Elastic Range.

SCANLAN, R. H.: A Note on Analysis of Beam-Columns under Arbitrary Lateral Load and End Restraint.

MINORSKY, N.: Energy Fluctuations in a van der Poel Oscillator.

MARIN, JOSEPH: Stress-Strain Relations in the Plastic Range for Biaxial Stresses.

DEVLIN, JAMES A., WALLACE M. MCNABB and FRED HAZEL: Preparation of Vanadium Pentoxide Sols by Ion Exchange.

COULSON, THOMAS: The Story of The Franklin Institute.

DUBILIER, WILLIAM: Development, Design and Construction of Electrical Condensers.

THE BARTOL RESEARCH FOUNDATION

The Bartol Research Foundation is engaged in the following activities:

1. Researches on nuclear physics, cosmic rays and allied phenomena under a contract with the Office of Naval Research.
2. Researches and development connected with the construction of a 5 to 10 million volt positive ion electrostatic generator for work in nuclear physics. This project is being sponsored jointly by the Office of Naval Research and by the Bartol Research Foundation itself.
3. Researches of a restricted nature pertaining to thermionics and sponsored by the Bureau of Ships.
4. Allied researches sponsored by the Bartol Research Foundation itself.

Some of our most spectacular work has been in the field of cosmic rays. During the year, our personnel (Mr. Peter A. Morris and Mr. David Seymour) have flown in a B-29 bomber with 2145 lb. of cosmic-ray apparatus and have completed 141 hr. of flight at 30,000 ft. and at 25,000 ft. for the purpose of investigating the variation of cosmic-ray intensity of different kinds of rays with altitude. We have also been concerned in the measurement of showers of particles produced in lead at these altitudes by the primary cosmic rays. Such investigations have importance in throwing light upon the nature of the primary radiation and upon the various processes which are associated with its passage through the atmosphere.

Last summer also, Mr. M. A. Pomerantz and Dr. Frank L. Hereford, Jr. made investigations on the summit of Mount Evans, the former for the purpose of investigating cosmic-ray absorption in dense materials at various altitudes, and the latter for the purpose of determining the way in which the number of cosmic-ray particles of different kinds varies with altitude.

Mr. Pomerantz has also continued his experiments in which apparatus is carried aloft by balloons to altitudes comparable with 25 miles. The records of the apparatus are telemetered back to the laboratory, where they are recorded and analyzed. One purpose of these flights is to investigate the nature of the cosmic radiation in regions where the amount of atmosphere above is so small that we can be said to be dealing with the incoming primary rays themselves, uncontaminated by the extraordinarily complex phenomena associated with their interaction with the atmosphere. One important fact brought out by Mr. Pomerantz' investigations is the experimental verification of the fact that at the "top of the atmosphere" the primary cosmic radiation is of practically equal intensity in all directions at these latitudes. Such investigations as these have also an important bearing upon the effect of the earth's magnetic field in its relation to the radiation.

The small 2 million volt positive ion Van de Graaff generator has been brought to a stage of extremely satisfactory operation and during the year, in the hands of Dr. Emmett L. Hudspeth and Mr. Charles P. Swann, has yielded important results bearing upon the structure of the nucleus of the atom. This generator was originally designed by Dr. W. E. Danforth and Dr. E. L. Hudspeth and was brought to a preliminary stage of operation before the war. During the war it remained dormant, but following the war, work on its development continued in the hands of Dr. E. L. Hudspeth, Dr. C. E. Mandeville, Mr. Charles P. Swann and Mr. Robert Pfeiffer (the Head of our shop), so that we now have a very serviceable machine which could not be duplicated by purchase for ten times the amount which it cost us to build it.

No further reference will be made at this time to the large generator referred to under (2) since that will be the subject of a separate article in the JOURNAL. It will suffice to say that considerable progress has been made and most of the essential parts of the new machine have already been constructed under the general design and guidance of Dr. Hudspeth, Mr. Charles Swann and Mr. Pfeiffer.

Dr. C. E. Mandeville has been engaged upon a number of researches pertaining to the mechanisms associated with the disintegration of the various radioactive isotopes which the atomic piles of this generation are now able to produce, and his work in this matter has been greatly facilitated by the development of Geiger counters of extremely short "resolving time," times so short that the instant of operation of the counters is defined to something of the order

of one hundredth of one millionth of a second. In the development of these counters, we have relied very much upon the ever-ready skill of our glassblower, Mr. A. G. Nester.

Various researches concerned with the mechanisms of Geiger counters and with the processes which occur in them are under way. Researches pertaining to the absorption of cosmic radiation of different qualities by various substances are also in progress.

One or two years ago, when we were considering the future of the laboratory as regards the nature of the equipment which it should secure for the production of high energy particles, we started an investigation on what is called a linear accelerator. While we finally decided to concentrate upon the new Van de Graaff generator as the Foundation's special piece of equipment in the nuclear physics field, Dr. B. L. Miller has continued work on the linear accelerator and has brought it to a stage where we may envisage a useful subsidiary tool for nuclear physics investigations. Quite apart from the development of this tool, however, the knowledge gained in the work connected with it—knowledge having a close relation to the field of microwaves—is felt to be a distinct asset to the laboratory in view of the likelihood of such waves playing a vital role in some of the researches of the futrue.

The work on thermionic emission has been carried out under the immediate supervision of Dr. W. E. Danforth. Since, however, it is of a restricted nature, it is not possible to report upon it in any detail.

LIBRARY

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

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RECENT ADDITIONS

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VALE, JOHN W. The Aviation Mechanic's Aircraft Manual. 1949.

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GLOAG, JOHN AND BRIDGWATER, DEREK. A History of Cast Iron in Architecture. 1948.
RADIO CORPORATION OF AMERICA. The Architects Manual of Engineered Sound Systems. 1947.

ASTRONOMY

ALTER, DINSMORE AND CLEMINSHAW, CLARENCE H. Pictorial Astronomy. 1948.

CHEMISTRY AND CHEMICAL TECHNOLOGY

FARADAY SOCIETY. The Applications of Infra-red Spectra to Chemical Problems. 1945.
KELLEY, WALTER P. Cation Exchange in Soils. 1948.
SCHWARTZ, ANTHONY M. AND PERRY, JAMES W. Surface Active Agents. 1949.

CIVIL ENGINEERING

INSTITUTION OF CIVIL ENGINEERS. The Civil Engineer in War. Three Volumes. 1948.

CRYSTALLOGRAPHY

LONSDALE, KATHLEEN. Crystals and X-rays. 1948.

ELECTRONICS

MILLER, HENRY A. Electronic Devices. 1948.
SPREADBURY, F. G. Electronics. 1947.

ENGINEERING

DAILEY, C. L. AND WOOD, F. C. Computation Curves for Compressible Fluid Problems. 1949.

LAMMEREN, W. P. A. VAN; TROOST, L. AND KONING, J. C. Resistance, Propulsion and Steering of Ships. 1948.

FOOD

SHERMAN, HENRY CLAPP. Selected Works of Henry Clapp Sherman. 1948.

MANUFACTURE

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MATHEMATICS

FAULKNER, T. EWAN. Projective Geometry. 1949.

HARDY, G. Ramanujan; Twelve Lectures on Subjects Suggested by His Life and Work. 1940.

LEDERMANN, WALTER. Introduction to the Theory of Finite Groups. 1949.

RYBNER, JØRGEN. Nomogrammer over Komplekse Hyperbolske Funktioner. 1947.

METALLURGY

AMERICAN SOCIETY FOR METALS. Fracturing of Metals. 1948.

WATT, D. S., Editor. Symposium on Metallurgy of Steel Welding. 1948.

PETROLEUM

PUGH, B. AND COURT, J. M. A. Fuels and Lubricating Oils for Internal Combustion Engines. 1949.

PHARMACY AND PUBLIC HEALTH

The Chemistry of Penicillin. 1949.

PHYSICS

BINDER, RAYMOND CHARLES. Fluid Mechanics. 1949.

GORTER, C. J. Paramagnetic Relaxation. 1947.

HOTTEL, H. C.; WILLIAMS, G. C. AND SATTERFIELD, C. N. Thermodynamic Charts for Combustion Processes. Part 2. 1949.

MARGENAU, HENRY; WATSON, WILLIAM W. AND MONTGOMERY, CAROL G. Physics, Principles and Applications. 1949.

SYNGE, JOHN LIGHTON AND GRIFFITH, BYRON A. Principles of Mechanics. Second Edition. 1949.

RADIO

MACLAURIN, WILLIAM R. Invention and Innovation in the Radio Industry. 1949.

RAILROADS

BURGESS, GEORGE H. AND KENNEDY, MILES C. Centennial History of the Pennsylvania Railroad Company. 1846–1946. 1949.

SCIENCE

GALILEI, GALILEO. Dialogues Concerning Two New Sciences. 1946.

THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

Abstract of* Physical Testing of Asphalts and Similar Materials.—EDMUND THELEN.[1] In order to formulate an asphalt, pitch, or similar material, which will give satisfactory service in a particular application, two types of information are required: first, the use for which the material is intended, and second, how to formulate a material with the desired properties.

It has been found that most of the working properties which an asphalt must possess, if it is to give satisfactory service, are essentially rheological in nature. In Table I are listed fifteen common working properties which are considered to be functions of one or more of five basic rheological properties, measured at various temperatures and rates of shear. Thus, if the yield values, mobilities, and elasticities of an asphalt are known over a wide range of temperatures and rates of shear, and if the vibration resistance and work of adhesion to the solid to which the asphalt is to be applied are known, a great number of the working properties of the material can be predicted.

It has also been found that a knowledge of these rheological properties provides an insight into the colloidal nature and composition of an asphalt, and hence, greatly assists in the development of formulae for asphalts with satisfactory working properties. However, the correlation of rheological data with colloidal compositions is not expounded in this paper.

TABLE I.—*Correlation of Working Properties with Rheological Properties.*

Desired Working Property	Yield Value	Mobility	Elasticity	Work of Adhesion	Vibration Resistance	Temperature	Rate of Shear
Fast flow through applicator	Lo	Hi				Pouring	100 sec.$^{-1}$
Great strength of bond	Lo	Hi	Hi	Hi		Ambient	10^{-6}
Complete wetting of surface	Lo	Hi	Hi	Hi		Pouring	10^{-4}
Great hardness	Hi	Lo	Lo			Ambient	0.01
Soft penetration	(Lo)	Hi	Hi			Ambient	0.1
Great ductility		Hi	Hi			Ambient	2
Freedom from sagging	Hi	(Lo)	(Lo)			Ambient	10^{-6}
Freedom from stickiness	(Hi)	Lo	Lo	Lo		Ambient	0.1
Great fatigue resistance	(Hi)	(Lo)	(Hi)		Hi	Ambient	100
Ability to seal self	Lo	Hi	Hi			Ambient	10^{-6}
Ability to withstand low pressure	Hi	(Lo)	(Lo)			Ambient	10^{-6}
Freedom from cracks on cooling	Lo	Hi				Ambient	10^{-4}
Freedom from cracks on aging	Lo	Hi				Ambient	10^{-8}
Great pliability	(Lo)	Hi	Hi			Cold	1
Great impact resistance (shock)	(Hi)	(Hi)	Hi			Cold	100

Yield value is the intercept on the shearing stress axis, of the shearing stress–rate of shear curve. Mobility the slope of this curve, is the ratio of the rate of flow to the net shearing stress causing it. Elasticity is the rate of flow per unit shearing stress, when the shearing stress is less than the yield value. Work of adhesion is the energy required to separate the asphalt from a superficial surface of unit area. Vibration resistance is the number of cycles of known acceleration, required to cause failure.

Temperatures and rates of shear are those at which the working property is of greatest importance. They are comparative only and are not to be taken literally, since the desired working properties themselves are not literally defined.

Parentheses indicate that the rheological properties concerned are of subordinate importance.

The correlations shown in Table I between the desired working properties and the basic rheological properties are discussed, and methods for measuring the rheological properties, are presented as follows:

* Paper presented by Edmund Thelen, the author, before the Annual Meeting of Association of Asphalt Technologists, at Detroit, Mich., February 15, 1949, and to be published in its *Proceedings*.

[1] Senior Research Engineer, The Franklin Institute Laboratories for Research and Development, Philadelphia, Penna.

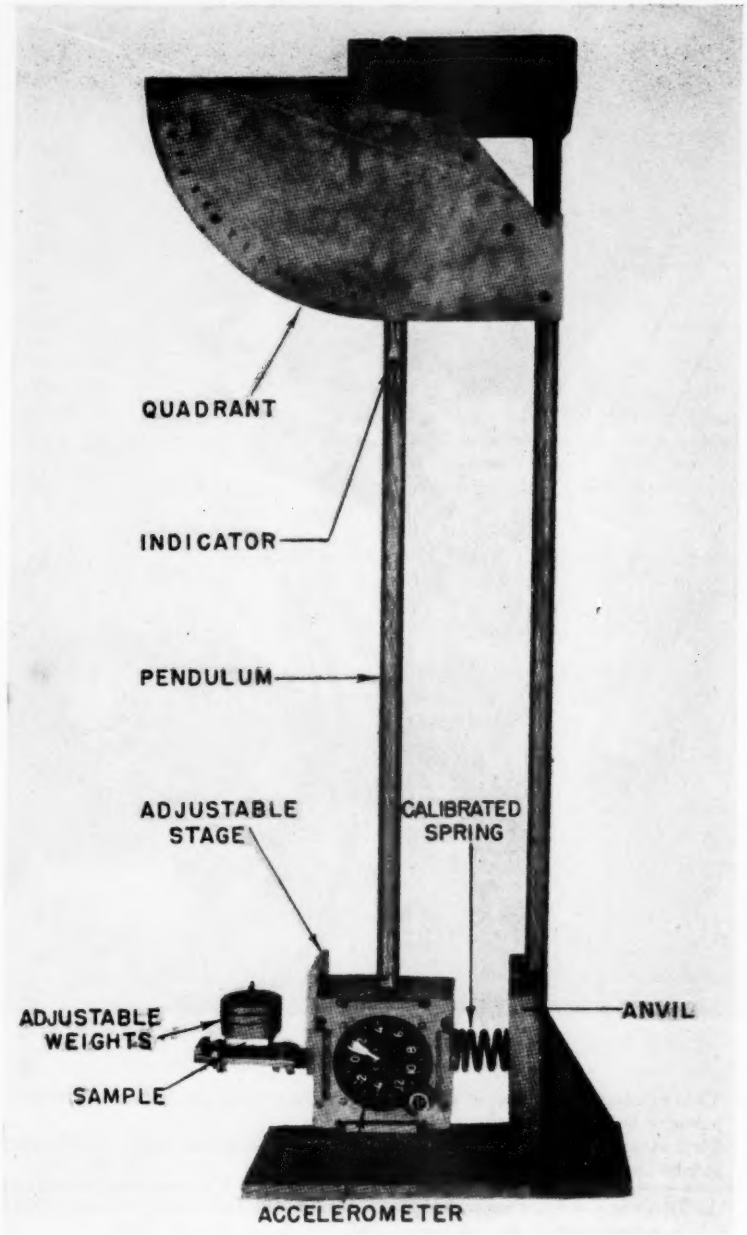

FIG. 1. Impact tester.

FIG. 2. Vibration tester.

a. Yield values and mobilities at pouring temperatures, using the Stormer viscosimeter and a new technique.
b. Yield values and mobilities at ambient and cold temperatures, using A.S.T.M. penetrometer by the method of successive penetrations.[2,3,4]

[2] E. THELEN, *J. Appl. Physics*, Vol. 8, pp. 135–137 (1937).
[3] E. O. RHODES AND E. W. VOLKMANN, *ibid.*, Vol. 8, pp. 495–496 (1937).
[4] W. W. PENDLETON, *ibid.*, Vol. 14, pp. 170–180 (1943).

c. Yield values, mobilities, and elasticities under "creep" or "cold flow" conditions, at very low rates of shear, using the method of Trouton.[5]

d. Impact resistance at 0° F., measured in terms of either the minimum force or the total energy required to produce failure, using specially developed equipment. The impact-force tester is shown in Fig. 1. In the impact-force test, the sample is molded between two standardized test panels, forming a prism 1" × 1" × ¼". The tester and the panels are held at 0° F. overnight. In running the test one panel is clamped to the pendulum, and to the other a known weight is affixed. The pendulum is dropped through successively larger angles, with an attached spring controlling its rate of deceleration as it hits the anvil. The impact force is calculated from the weight of the mass attached to the top panel, and the deceleration is measured by the accelerometer built into the pendulum.

e. Surface tension and work of adhesion to a solid surface by the sessile drop method of Dorsey,[6] optically projecting the silhouette of the drop onto a screen where it can be measured readily.

f. Vibration resistance under oscillating stresses of various magnitudes. In this test the sample is poured between two standardized test panels, forming a prism 1" × 1" × ¼". One of the two panels is held stationary and the other is clamped into a moving head driven by a cam through a predetermined amplitude of oscillation. As the test proceeds, a cleavage develops parallel to the panels. The test is terminated when the cleavage extends over substantially the entire area. In many cases during the tests, the colloidal particles in the sample appear to aggregate into particles visible to the eye. This vibration tester is shown in Fig. 2.

These rheological test procedures and conceptions are useful in the formulation of improved asphalts, pitches, waxes, and other compositions of a highly viscous or visco-plastic nature. The presence in the composition of finely-divided fillers, secondary gel structures, and other materials, does not affect the test results so long as the composition is essentially homogeneous in nature.

It is found that the rheological properties of such compositions vary systematically with the experimental parameters, and hence, from relatively few measurements, the rheological properties can be interpolated for a wide range of conditions.

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[5] F. E. TROUTON, *Proc. Roy. Soc.*, Vol. 77A, p. 426 (1906).

[6] N. E. DORSEY, *Nat. Bur. Standards Sci. Paper No. 540* (1926).

BOOK REVIEWS

INDUSTRIAL ELECTRICITY, VOLUME II—ALTERNATING CURRENTS, by William H. Timbie and Frank G. Wilson. 781 pages, 14 × 22 cm., illustrations. New York, John Wiley & Sons, Inc., 1949. Price, $5.96.

Volume II of "Industrial Electricity" is essentially a textbook on alternating currents and alternating current machinery. In subject matter it does not differ materially from most texts on this subject. The manner of presentation, however, adapts the book to students of varied backgrounds, since an effort has been made by the authors to avoid complex theory development in a rigorous mathematical fashion. Nonetheless, the theory is well developed to the extent that the student not only learns what happens in a-c. circuits, but is also able to cope with problems on the subject.

The book can be divided into six major categories covering fundamentals, alternating current machinery, transformers, transmission lines, converters and rectifiers, and appendices containing information necessary to the working of problems.

"Industrial Electricity" contains numerous problems, some of which have been worked through by the authors as examples, and many of which are presented for student exercises. The problems are practical and should afford the student excellent opportunity to test the progress of his learning.

The book differs from older texts on the subject in that it touches on some of the more recent developments in the field, such as the super-synchronous motor, and autosyn and selsyn control equipment and applications.

The illustrations are well chosen in that they give the student some idea of the mechanical as well as the electrical problems involved in the design and construction of alternating current machinery. Also worthy of comment are the summaries at the end of each chapter. These summaries are concise reviews of the material presented in each chapter, and should serve to refresh the student's memory on the details of each chapter. They also point up the more important aspects of the subject material. One further item of interest is that the authors have not been negligent of the economic factors involved in the construction and use of alternating current equipment. This economic emphasis is particularly noticeable in the chapters devoted to transmission lines.

ROBERT S. GRUBMEYER.

NATURAL PRODUCTS RELATED TO PHENANTHRENE, by Louis F. Fieser and Mary Fieser. Third edition. xiv + 704 pages, 15 × 23 cm., tables and structural formulas. New York, Reinhold Publishing Corp., 1949. Price, $10.00.

This is a new edition of the book which has appeared twice, in 1936 and 1937, under the title "Chemistry of Natural Products Related to Phenanthrene," by Louis F. Fieser. It is listed as American Chemical Society Monograph No. 70.

The change in title from the previous editions reflects not only the increased emphasis on metabolism, physiological activity, and pharmacology, but also the growing importance of the correlation of physical properties with structure in this field. Such physical means as infrared and ultraviolet spectroscopy, X-ray analysis, tracer isotopes, and the method of molecular-rotation differences based upon differences in optical activity in the case of similar molecules, have contributed greatly to the study and, in many cases, to the solution of structural problems.

The book represents a complete "overhauling" of the original work, covering journal sources up to the fall of 1948. It has grown to twice its former size even though some sections such as those on the chemistry of phenanthrene, carcinogenic hydrocarbons and triterpenoid saponins have been omitted because they do not fall strictly within the scope defined by the title. Quoting from the preface: "By 1937 most of the important physiologically active steroid

hormones and vitamins had been isolated and their structures established, but very little was known of the stereochemical configurations. Extensive study of the steroids have culminated in recent years and months in the complete solution of all the major problems concerned. This, therefore, is a particularly appropriate time to present a revision. . . ." Partial and total syntheses of natural products and closely related substances, which have also figured largely in recent research, are discussed in detail.

Following a discussion of the opium alkaloids and resin acids, comprising about 90 pages, almost a third of the book is devoted to a treatment of the structure, physical properties, and chemical reactions of the sterols and the bile acids. Chapters dealing with sex hormones, cortical hormones, steroid metabolism, cardiac poisons, steroid saponins, and steroid and terpenoid alkaloids follow.

The final chapter, written by Richard B. Turner, of Harvard University, is devoted to a critical survey of stereochemical evidence for structure assignments in the steroid group. Much of the evidence is based upon the modern theory of displacement reactions, which is very well presented in the brief treatment which it receives. Perhaps it should have been mentioned that elimination reactions may accompany bimolecular substitutions (E 2, S_N2) as well as unimolecular substitutions. The statement that "Stabilization of the carbonium ion can . . . be effected by ejection of a proton" (page 638) may call for elucidation. The value of the application of modern theories of organic mechanisms in this extremely complicated field effectively refutes the contention that they are of use only in the case of the simplest organic reactions.

The book is well printed and remarkably free from typographical errors. The system adopted for numbering of footnotes is somewhat confusing; on various pages, e.g., pp. 168, 288 and 608, identical superscripts indicate different references. In general, however, the reviewers have nothing but praise for this readable, clear and concise treatment of a difficult subject. The style is excellent and the tables and structural formulas are carefully set out.

WM. B. MELDRUM AND O. T. BENFEY.

ENGINEERING LAMINATES, edited by A. G. H. Dietz. 797 pages, 15 × 23 cm., illustrations. New York, John Wiley & Sons, Inc., 1949. Price, $10.00.

A structural material composed of two or more layers is an engineering laminate. Such laminates may be of wood, wood and concrete, plastics-based materials, aluminum-clad products, copper and copper-alloy clads, various alloy-clad steels, composite-glass materials, and rubber. "Engineering Laminates" is a symposium of papers on the important laminates of engineering significance written by specialists in each field.

The book is well written, well organized and contains important and useful engineering information. An introduction tells the reader that laminated wood dates back to at least 2780 B.C., so that lamination is not a new subject. It is true, however, that laminates as structural materials have advanced rapidly in the last ten years, particularly during the war when many materials became scarce. Chapter I discusses very thoroughly and ably the strength of laminates and sandwich structural elements. Commencing with Hooke's Law and ending with practical design formulas, it describes the bending of beams and plates, and the buckling of plates, shells and columns, and presents several illustrative problems. Chapter II comprehensively surveys the field of adhesives for cementing the various laminates together, explaining the theories of adhesion, the various adhesive types, the general methods of application and properties of bonds. The last section provides the sources of the various specification standards, information which is always valuable to the engineer.

Following the introductory chapters are twenty chapters dealing with specific laminates. There are chapters containing design information for structures in glued woods, in plywoods and in laminated wood-concrete, with examples of design procedure in each. Plastics-based laminates and plastic-surfaced plywoods, each with their physical properties, are discussed. The uses and structure of sandwich-type building boards and structural-sandwich construction are described. Methods of preventing corrosion in certain structural materials are explained in chapters on aluminum-clad products, hot-dipped aluminum-coated steel, copper and copper-

clad alloys, nickel-clad, monel-clad and inconel-clad steels, and stainless clad steel. Other methods of inhibiting corrosion and increasing wear are discussed in chapters on cast-laminated metallic materials, hard surfacing by fusion welding, and sprayed metals. Glass-lined steel equipment, the making of glass-lined steel equipment and composite-glass structures for safety glass are described also. The two concluding chapters discuss rubber laminates and molded laminates and sandwich materials.

Not the least important attribute of the book is the many tables, charts and photographs dispersed throughout the book. The tables and charts contain engineering data and are useful for design. Also, each chapter contains extensive bibliographies, except in a few places.

"Engineering Laminates" provides the engineer, architect and student with valuable information on the brief histories, design procedures, manufacture and uses of important laminated structural materials and should be an excellent reference book for their libraries.

E. W. HAMMER, JR.

COMPUTATION CURVES FOR COMPRESSIBLE FLUID PROBLEMS, by C. L. Dailey and F. C. Wood. 33 pages, 24 × 29 cm., diagrams. New York, John Wiley & Sons, Inc., 1949. Price, $2.00.

The advent of transonic and supersonic airplanes and missiles has brought to the design engineer the importance of practical application of the theory of compressible flow. Since the war numerous publications on this phase of the science have been proffered, each claiming an individual and helpful approach, but so far, all of them stem from the same basic relations and assumptions used in simplifying the fundamental theory of compressible flow. When computation curves, representing the relation between certain parameters in the equations, are used in lieu of numerical computation, the important thing to consider is the accuracy for which the curves were intended. This principle is exercised through the discrimination of the user.

In this publication, the authors claim a consistent accuracy on the order of one per cent in the manner of presentation of the curves for the relations covered. During this reading, certain computations were made using the data of Fig. 1, Section II Plane Shock relations and the presentation, at least in the region of these calculations, was well within the accuracy of practical application deemed acceptable today.

The computation curves of this publication are presented in three sections. The first includes the local point functions of Mach number which describe the state of the gas, and includes relations to determine the changes in the flow variables caused by heat addition in a constant area channel. The second section gives the relations for flow across a plane oblique shock wave and the Prandtl-Meyer expansion relation. Because of the nature of the graphs used, the normal shock is included as a special case of the oblique shock, rather than as a special case of heat addition. The third section gives the results of the Taylor-Maccoll theory for flow past a cone at zero angle of attack. The Mach number, pressure, streamline direction for the conical flow field, and boundary values at the shock wave and cone surface can be obtained.

The computation curves are presented in this publication as supplementary material to the book, now familiar to most students, "Aerodynamics of a Compressible Fluid," by Liepmann and Puckett.

It is believed these curves may be useful in such design problems as wind tunnel nozzles and diffusers, jet engines, and in the estimations of performance.

The first part of this publication is devoted to a text explaining the presentation of the curves and deriving the formulas used.

MAX W. BERG.

NUMERICAL METHODS OF ANALYSIS IN ENGINEERING, edited by L. E. Grinter. 207 pages, illustrations, 16 × 24 cm. New York, Macmillan Company, 1949. Price, $5.80.

The power and importance of numerical analysis as an engineering tool is very seldom brought to the full attention of undergraduate engineering students. And unless practicing

engineers find themselves confronted with problems concerned with a phase of research, design, or development which requires mathematical analysis, they would not need a knowledge of the subject matter of this book. But those engineers who must substitute methods of successive corrections for rigorous mathematical analysis, should be extremely interested in this volume. Many times an approximate solution is satisfactory, especially where it is just impossible or impractical to arrive at an exact solution. This situation can occur in many branches of engineering, since physically different phenomena can often be described by the same set of mathematical expressions. Consequently, emphasis placed on demonstrating methods and techniques of numerical analysis as is done in this text is well spent, since these methods apply equally well to problems in such diverse fields as structures, vibrations, elasticity, torsion, heat transfer, and electrical flow, to name a few applicable fields in engineering and science.

Methods of successive correction have been studied intensively in the past twenty years, primarily with respect to the numerical solution of two-dimensional field and plate problems, attacked both from the mathematical and physical approaches. The subject matter of this volume considers specific and interrelated methods using both approaches.

The ten chapters of the book are separated into four sections. The first section is devoted to numerical methods based upon physical concepts, and as an introduction the first chapter is a reprint of Hardy Cross's paper on moment distribution, from which basic paper his followers have greatly contributed to the methods of successive corrections based on physical principles. The second section is concerned with numerical solutions of equations for state of stress. Here are presented papers by Southwell, Shaw, and Frocht on relaxation methods and special solutions of Laplace's equation of interest to electrical engineers and photoelasticians. Applications to heat transfer are the subject of the third section, and surveys and bibliographies of numerical methods are the subject of the fourth and last section. Each chapter concludes with an extensive and well chosen bibliography of books and papers useful for further investigation of specific problems.

The chapters are arranged in order of difficulty, allowing the reader to extend his comprehension and coverage of the field of numerical analysis. The serious reader in any field of engineering or science should find in this book something of interest and application to his own work.

S. CHARP.

PHYSICS, PRINCIPLES AND APPLICATIONS, by H. Margenau, W. W. Watson and C. G. Montgomery. 760 pages, 15 × 23 cm., illustrations. New York, McGraw-Hill Book Co., 1949. Price, $5.00.

This book is intended as a text for a college sophomore course in physics for those students who intend to specialize in engineering or the physical sciences. For a book of this type, the subject matter seems to be quite well covered. In fact it probably covers more material than the average college student at the sophomore level could properly cover in a one year course. This should not be thought of as a disadvantage, however, since it gives the individual instructor an opportunity to select and omit those topics that will best fit the needs of his particular students. The authors have indicated by stars at the beginning of certain paragraphs the topics that, in their opinion, should be omitted if one wishes to shorten the course. The problems which are based on these starred sections are also starred.

The book consists of fifty chapters and seven appendices. This book differs from many text books of the past in that it is not divided into sections such as, mechanics, heat, electricity and magnetism, etc. Some may feel that this is a disadvantage since it does not emphasize the various branches of physics as separate topics, but others will prefer it since it gives more unity and continuity to the course.

The title of the book implies that the practical applications of physics are emphasized. In view of the necessary limitations of space this phase of the subject is treated fairly well. There are numerous other instruments and processes familiar in everyday life that could have been mentioned as important applications of physics had space permitted. The instructor

will probably wish to discuss some of these additional applications, according to the interests of his students.

The chapter on meteorology should be very interesting to many students. It shows how physics can be applied to a subject that is of vital importance to almost everyone.

There are two chapters on electronics. The fundamental principles of electron tubes and simple electronic circuits are discussed. This is followed by brief discussions of several important applications of electronics such as: radar, television, crystal rectifiers and electron microscopes.

The last two chapters are entitled Atomic Structure and Nuclear Physics, respectively. In these two chapters a great many new concepts are presented to the student in rapid succession. The student should have no particular difficulty with this part of the book if it is covered slowly and thoroughly.

Although the presentation of the material does not differ greatly from that of other good books in the field, this book should measure up well to the purpose for which it was written. It should enable the student to lay a good foundation for his later work in the physical sciences and engineering.

MARSHALL D. EARLE.

PHYSICAL ASPECTS OF COLOUR, by P. J. Bouma. 312 pages, 16 × 23 cm., illustrations. Eindhoven (Netherlands), N. V. Philips Gloeilampenfabrieken, 1947. Price, $5.50.

The Philips organization has recently embarked upon a policy to publish a series of books written by some of their scientists on subjects investigated by that concern. This book "Physical Aspects of Colour" is the first such volume to be printed in English.

The subject of color can be treated in any one or combinations of different points of view, depending upon primary interest. The combined effects of color can be discussed with reference to psychology, psychophysics, and physics. While reference to these three fields must be made for completeness, the author of this volume has preferred to be concerned only with the last class of problems, in particular, the entire subject is approached from the point of view of experimental physics and illuminating engineering, with prime interest being in the quantitative expression of colors by sets of identifying numbers, and the means of measuring and calculating these identifying numbers. Where physiological and psychological questions are considered, they are discussed again from the experimentalist's point of view with but brief reference to theory.

In the fourteen chapters of the book, the author presents a highly technical subject cast in a form which requires only a secondary school knowledge of mathematics and physics. Following an introduction of the color triangle and the representation of color sensations on a plane diagram and in space, the important C.I.E. co-ordinate system is discussed, with emphasis on the properties and transformations of the XYZ system. To enable the reader to carry out practical calculations, a chapter is therefore devoted to computing procedures for the cases of light sources, colored surfaces, dominant wave length and colorimetric purity.

Special light sources, objective and subjective colorimetry, a survey of the problems of defective color vision, color discrimination and sensation, methods of color description, and practical engineering applications are treated as separate subjects.

The author accomplishes his intended purpose and the reader is facilitated in learning the tools of physical color specification. In addition, the zealous reader can appreciate the opportunity to read more of the professional literature of this most interesting subject through good use of the reference material.

S. CHARP.

MODERN INTRODUCTORY PHYSICS, by Ira M. Freeman. 491 pages, 15 × 23 cm., illustrations. New York, McGraw-Hill Book Co., 1949. Price, $4.50.

It would be difficult for any review to do justice to this book. Both the author and publisher deserve all the credit a reviewer can heap upon them for a job well done.

The author admirably states the purpose and form of this book in the preface and then

proceeds to live up to the expressed intent in the pages that follow. The author quotes a New York Times editorial which reads: "A professor of English or of history does not usually cherish the illusion that his students are all potential novelists and poets or authorities on feudalism or eighteenth century liberalism. Literature, history, philosophy are taught as cultural subjects. In science it is otherwise. Most teachers of chemistry, physics and biology lecture as if the young men and women before them were to become professional laboratory or field workers. The procedure is sound enough for engineering schools, but hardly for liberal arts colleges. It is the importance of science in modern society, the way that scientists think, the relations of the scientists to his environment that need to be taught."

Professor Freeman goes on to state how this book approaches the problem: "The book makes no effort to 'cover' physics. (In one connotation the word implies a sort of suffocation or interment process!) Rather, the aim is to be selective instead of encyclopedic, to be penetrating but not needlessly detailed, to be meaningful without being technical.

"Specifically, the text tries to give more attention than is usual at this level to the historical and philosophical aspects of the science; for the author feels that these are features which can most readily make the subject come alive for the nonscience student and help him to see that physics can be a humanistic study with value and meaning for everybody."

The first chapter entitled "The Method of Science" discusses "The Scientific Method" and sets up the principles that are exemplified in the physics discussed in the remainder of the book. Subsequent chapter headings are: Physics as an Exact Science; Force and Equilibrium; Motion; Force and Motion; Mechanical Energy; Heat Energy and Molecules; Rotation and Vibration; Waves; The Nature of Light; Ray Optics; Dispersion and Spectra; Diffraction, Interference, and Polarization of Light; Electrostatics; Electric Currents; Electromagnetism; Electrons; Isotopes, X-Rays, and Natural Radioactivity; Origin and Early Development of the Quantum Theory; Waves and Corpuscles; The Newer Quantum Theory; Nuclear Disintegration; and The Structure of the Nucleus.

The author wisely guides the student throughout the text lest he be led astray. In the chapter "Ray Optics" for example one paragraph reads: "It would be tempting to conclude on this evidence that the corpuscular theory adequately explains the phenomenon of refraction and to consider the matter settled. However, it must always be remembered in scientific work that no theory may ever be considered final, since it may conceivably fail to meet the test of the very next experiment that is performed. Moreover, there always exists the possibility that an entirely different theory, not resembling in the least the one in vogue, may be devised and that the new theory may be equally successful in accounting for the known facts. It may even turn out that the new theory ultimately succeeds in accounting for facts later discovered, where the earlier theory does not. This has happened many times in the history of science; it happened in the case of the theory of light, as you will see."

At the ends of the chapters one will find sections of Summary, Reading References, Film References, Experiments, and Exercises. In the conclusion to the entire text the author says: "Recent advances in technology based on scientific discoveries have hurtled us into a new period in history far more critical for humanity than any previous one. If any single piece of evidence was needed, the discovery of how to release subatomic energy on a large scale brought home to thoughtful persons the realization that social problems and science are inextricably linked. To blame science for this newest and most stupendous of its offshoots would be futile. Rather, the solution to our difficulties, if we are to survive, is to learn to apply scientific thinking to our social and political problems."

If possible, take Ira M. Freeman's Introductory Physics course at Rutgers. Otherwise, read the text "Modern Introductory Physics."

D. B. HOUGHTON.

ROCKET PROPULSION ELEMENTS, by George P. Sutton. 294 pages, 14 × 22 cm., illustrations, plates. New York, John Wiley & Sons, Inc., 1949. Price, $4.50.

This book presents the basic theoretical considerations along with practical design problems encountered in the design of a rocket propulsion system.

The organization of material is particularly good. The chapter on Rocket History, while short, provides interesting background with a well planned transition in remaining chapters through Thermodynamic Relations, Performance Calculations, Systems and Testing.

The text is amply illustrated with graphs, tables, sample calculations and photographs. Each chapter concludes with problems, references and symbols which are applicable to that chapter. There is an excellent balance between theory and practice.

The chapter on Rocket Testing omits mention of an important consideration—that of noise reduction. The high acoustic output of rocket motors must be considered as to psychological and physiological effects upon nearby workers and residential areas.

It is believed that this book provides by far the most comprehensive coverage of rocket propulsion under one cover to date and is highly recommended for all workers in this fast moving field.

A. M. PICHITINO.

ESSENTIALS OF PHYSICS, by Carl F. Eyring. 405 pages, 14 × 21 cm., drawings, illustrations, and plates. New York, Prentice-Hall, Inc., 1948. Price, $5.00.

This book appeared for the first time twenty years ago, and also in later editions, under the title, "A Survey Course in Physics." It has now been partially rewritten, slightly enlarged, and given the new title above. It is intended to cover a short course, one semester, for students who are not going to study any more physics. For this purpose it is admirably suited.

This reviewer must confess to a long-standing prejudice against such a survey course in physics and the type of textbook that usually goes with it. Yet, once begun, it was impossible to put this book of Professor Eyring's down without reading to the end! It was too interesting. The subject matter is presented clearly, concisely and extraordinarily simply. It should, for the most part, be easily comprehended by a student who is studying physics for the first time. The author is to be congratulated upon achieving his goal with such success.

There are no "problems" and very few "formulas." One would suppose that the elimination of most of the mathematical side of physics would "denature" it to an impossible degree. The author has demonstrated that it is not necessarily so. The difficult task of selecting the topics to be treated has been done with great skill. It is only when difficult conceptions, such as double refraction and interference, are encountered that the brevity of presentation fails to give a clear understanding. Here, too, the illustrations represent the ideas of the artist rather than the actual appearance of the phenomena. The chapter entitled, "Inside the Atom" also leaves something to be desired. This would be very stiff reading for the student, since the phenomena encountered are too complex to be described satisfactorily in so few words. It would have been better to omit some of the topics and devote the space to amplifying the rest.

FREDERIC PALMER.

FIELD ENGINEERING, by William H. Searles, H. C. Ives and P. Kissam. Vol. I, 414 pages, Vol. II, 422 pages, 11 × 18 cm., illustrations, plates. New York, John Wiley & Sons, Inc., 1949. Price, $6.50.

It is now 69 years since the first edition of this handbook appeared, this present edition being the twenty-second. This long period has seen the rapid growth of railroads, as well as progress in the science of railway engineering. But the field methods used by civil and railroad engineers have been but little changed, primarily because the kind of mathematics embodied in their specialty is essentially a series of special applications of plane trigonometry and geometry.

The handbook of field methods was originally written and has since been revised with several aims in mind: to present the general subjects of railway field engineering in a logical order; to classify several special problems for ready reference; to use a convenient notation with engineering formulas always presented in a form best adapted to convenient numerical computation; and to present a collected set of tables which are constantly referred to by railway design engineers. These aims are adhered to in this edition as well, although in preparing the

present volume, Professor Kissam has taken pains to clarify and rewrite parts of the earlier text, especially to bring the material up-to-date.

The first volume consists of twenty-one chapters: four devoted to reconnaisance, the preliminary survey and mapmaking and the location survey; six devoted to simple, compound, reversed, spiral and highway curves and turnouts and crossings; five to earthwork, cross-sections, and haul and mass diagrams; five devoted to construction, track-laying, and grades, curves, and levels; and one devoted to the adjustment of instruments. In each of the chapters are found detailed instructions and sample computations in a form which can readily be used in the field.

The second volume contains fifty-two tables of civil engineering interest, many of them having been proof-read and corrected over the years since the original publication; they are therefore exceptionally accurate. An enumeration of the tables is impossible in this review, but it can be noted that several have never been published except in this new edition.

S. CHARP.

FLUID MECHANICS, by R. C. Binder. Second edition, 361 pages, 16 × 23 cm., illustrations. New York, Prentice-Hall, Inc., 1949. Price, $4.25.

The subject of fluid mechanics, treating of both liquids and gases, is so broad that there is scarcely any branch of engineering that does not employ some of its principles or phenomena in one form or another. Naturally, such a comprehensive subject is difficult to compress within the covers of a normal-sized volume, unless a common basis is found for treating all of the complicated flow phenomena for various fluids. This the author of this work has attempted to do by keeping uppermost the thought that the basic equilibrium and dynamical equations of flow are the same for all fluids, making due allowance for different properites of each. Exact physical concepts and common quantitative relations are emphasized to give the student a good physical picture of the flow phenomena as an aid to understanding and analyzing subsequent problems for himself.

The method of presentation practiced in this work is unique in that it is so simple and logical in its presentation, first, of the standard nomenclature and values used by a majority of writers and second, of the simple basic equations by which the various phenomena are described. This is followed by statements of the principal integrals without proofs and their solutions without too much detail. Examples are also solved and many others given for the student to learn by practice.

Likewise, there is a logical sequence of presentation of subject matter, beginning with statics and viscosity, followed by kinematics and dynamics. The introduction presents many of the more important fluid properties, physical laws and terminology. Fluid statics, kinematics of flow and the energy equations for steady flow are explained quite simply in the next three chapters. Viscosity is explained very clearly, and the methods of dimensional analysis and dynamic similarity introduced and employed wherever feasible. Following this, the various types of flow are treated in several chapters, both for air and liquids. Later chapters deal with the machinery of fluid mechanics such as pumps, turbines, couplings and torque converters.

This is an excellent work for the self-taught student as well as the college student in hydraulics, and should prove to be a handy reference for the practicing engineer.

F. R. SIMPSON.

AN INTRODUCTION TO COMPARATIVE BIOCHEMISTRY, by Ernest Baldwin. 164 pages, 12 × 19 cm., illustrations. Cambridge, University Press, 1948. Price, $1.75.

Biochemistry, though still an infant science, has attained the stature and importance of a separate branch of chemistry; however, it is in danger of developing disproportionately. The emphasis in present research is on problems of pharmaceutical and medical importance with only economic gains as the goal rather than on the overall chemical processes associated with life. The full value of biochemistry can only be realized by furthering the study of life in its

most elementary sense, and not specifically the problems of man alone. The task of the biochemist should be centered on the study of animals in general and not one in particular. If the above approach is not followed, biochemistry becomes a mere catchall for scattered data with no means of correlating facts with life functions. Comparative biochemistry provides the means of attaining this end.

Dr. Baldwin has written this little book for students about to begin biochemistry and for persons with some scientific background who are interested in the subject. Naturally such an extensive field must be approached from the very widest viewpoint, and in this brief volume only some specific topics can be covered while others are given cursory treatment or omitted entirely. However, the excellent bibliography furnishes the reader with a source of more detailed information. The standard topics of biochemical importance are covered; that is, the vitamins, enzymes, animal pigments, amino acids, purines, guanidines, and ureides. A very interesting approach to the theory of evolution from the standpoint of chemistry is presented. The author shows how osmotic pressure variations in animals depend on the media in which they exist and how their regulating mechanisms must be modified with changes in media, thus furnishing a means of tracing evolution by comparison of osmoregulatory mechanisms with animal levels.

The author accomplishes his purpose, which is to apprise the reader of some of the physical and chemical relationships between the internal and external environments of animals. The book gives the scientist and the nonscientist a little insight into some of the advances and problems of biochemistry and acquaints him with the vast possibilities of this rapidly growing field.

DONALD H. RUSSELL.

DESIGN OF STEEL BUILDINGS, by Harold D. Hauf and Henry A. Pfisterer. Third edition, 280 pages, 14 × 22 cm., illustrations. New York, John Wiley & Sons, Inc., 1949. Price, $5.00.

As the title of this book suggests, it is concerned with the general principles of structural design as applied to the framing of commerical, institutional, and residential type buildings. Both authors are simultaneously engaged in the teaching and practice of the methods which are set forth in this third edition, a textbook which may have as wide an appeal to the practicing structural designer and builder as it has to the undergraduate student and instructor.

Modern buildings are almost always constructed with steel frameworks, either for wall-bearing or skeleton construction, and their architectural and economic features usually give rise to several alternate designs. The choice of the most suitable structure requires not only a familiarity with structural design, but also a knowledge of comparative costs and field methods. These features are separately considered in this volume. In most of the book there are set forth detailed design procedures for what may be called unit assemblies or unit design. These principles are combined and reviewed in a most practical manner in a section devoted to a building design project which serves to assist in bridging the gap between academic work and professional practice.

For background, the reader is required to have a knowledge of the elementary principles of structural mechanics, even though some review is made in the text of basic statics and strength of materials in a consideration of reactions, shear, and bending moment due primarily to external forces. The forces acting within the beam which resist those applied forces are considered to develop the theory of beam bending and the design of beams, girders, lintels, and bearing plates. Riveted connections, plate girders, columns and struts, roof trusses, welded construction, and wind stresses in tall buildings are the subjects of other chapters, in each of which there is first presented the elementary theory, then detailed illustrative examples, and finally a number of problems which serve to make the design procedures more concrete. The building design for a small business edifice is the subject of the last chapter, and if completely and skillfully carried out by the student, then he has learned all the authors hoped.

The answers to selected problems are found in one of several appendices, others being concerned with tables of design information useful to the structural designer.

S. CHARP.

A NEW THEORY OF HUMAN EVOLUTION, by Sir Arthur Keith. 451 pages, 14 × 22 cm. New York, The Philosophical Library, Inc., 1949. Price, $4.75.

Since Darwin's time the study of evolution has undergone many advances in the physical and statistical branches, but there has been something in the nature of an opposition to extend the range and scope of anthropological studies. The conventional view of physical anthropology has been that man was descended from apes of the existing species, the European perhaps from the chimpanzee, the Negro from the gorilla, and the Mongol from the orangoutang. Of late years a belief has come to be held that man is not descended from any existing anthropoid but from some now extinct relative. The fact that all the races of mankind will readily interbreed has been held to show that the human species is really one, and must therefore be the offspring, if not of one pair, at least of a related group.

A prominent exponent of the modern theory is Sir Arthur Keith who, in his eighty-first year, has given in this book evidence in support of the "new theory." It is to be said in the author's favor that the exposition gives an aspect that will recommend the study of anthropology to many people who have turned aside from the aridity of a science which has sought its sustenance exclusively from the evidence of the distant past. The principal charm of the book, in this reviewer's eyes, resides in the attitude adopted by the author that the evolution of man is not merely a thing which occurred long ago and far away, but that it is a process continuing under our eyes. Viewed in this perspective it comes as a pleasant surprise to find how deeply "human nature" was implicated in the process of group evolution. Such factors as group isolation, inbreeding, marriage, sex differentiation and selection at first sight seem remote enough from the influence of human mentality but, in Sir Arthur Keith's skillful analysis, they turn out to be closely related. Nine of the essays in this volume are devoted to showing the rise of the mentality which characterized the "evolutionary units" or isolated groups of humanity during the primal period.

The author devotes much attention to the factors of nationalism and racialism which, he contends, are both traceable to the same evolutionary root. Later, he enters upon another phase of anthropological inquiry, the rise of new nations in the modern world, in which new nations have replaced native peoples of diverse stocks.

There appears small hope that this refreshing view of human evolution will escape from criticism but the author presents his case with a learning and scope which fills the lay reader with amazement, and which cannot fail to make converts. Much of the book's appeal lies in the simple lucid manner in which it is written.

T. C.

A TEXT BOOK OF PHYSICS FOR STUDENTS OF SCIENCE AND ENGINEERING, by J. Duncan and S. G. Starling. 1063 pages, 14 × 22 cm., illustrations. London, Macmillan and Co., Ltd., 1948. Price, $5.50.

Students of engineering in all its branches can profit through reference to this well established English physics text. Now in its completely revised second edition after numerous printings since its publication over thirty years ago, the volume covers all the usual subjects taught in an engineering physics course. However, while the use of differential and integral calculus is becoming prevalent in physics courses designed for engineering students in this country, these methods are considered in only certain subjects in addition to the algebraic methods of analysis.

The book is arranged in five parts as is the custom in the standard undergraduate physics course: dynamics; heat; light; sound; and magnetism and electricity. Principles and applications are considered together, and the intertwining of these make the subject matter more flavorful. In addition, there are found rather complete discussions of the classical laboratory experiments, with descriptions of instruments and methods of conducting the experiments. While the equipment of an individual laboratory may differ markedly from that described, the guidance given in this text should be of extreme assistance to any student.

Dynamic principles are treated with an experimental approach. Translatory and rotational motion, problems of forces, energy, and power, and hydrostatics and hydrodynamics

are the main dynamics subjects. The second part devoted to heat carries the reader through the problems pertaining to heat transfer for solids, gases and vapors. The detailed descriptions of pumps, heat engines, steam and internal combustion engines are useful for mechanical engineering laboratory experiments. In a similar manner the other three major subjects are presented in an extremely clear but non-mathematical manner, that is, no mathematics beyond algebra and trigonometry. Extremely practical in nature, the authors have taken care to explain everyday phenomena and simple mechanizations in terms of basic physical principles, for example: the hydraulic transmission of energy; expansion joints for heat systems; engine indicators; numerous optical measuring instruments; and others too numerous to mention.

As an aid in understanding the text, worked out examples are included in each section. The large number of exercises which appear at the ends of the chapters are more than sufficient for any classroom use. The answers to all numerical problems and a set of four-place logarithm tables are included at the end of the book.

S. CHARP.

THEORY OF GROUPS AND ITS APPLICATION TO PHYSICAL PROBLEMS, by S. Bhagavantam and T. Venkatarayudu. 234 pages, drawings. Andhra University, Waltair, India, 1948. No price.

This text is highly recommended to the theoretical and mathematical physicist. The theory of groups as a mathematical tool in the interpretation and solution of physical problems is comparatively new, and this treatment of such a problem is unique. The subject, with its applications, is of an advanced nature both in the mathematical and physical aspects. The reader should have a knowledge of atomic and molecular structure, quantum mechanics and advanced dynamics. The group theory is presented from a physical point of view first and later on, in a purely mathematical treatment. The subject is introduced by defining the Group with its associated properties and then stating the postulates. The various symmetry machines are treated completely with space grouping and point grouping.

There are numerous applications in the various fields of physics. The Schrodinger equation is developed and then expressed with Hamiltonian form. Solutions are sought which bring out the full significance of eigenvalues and Eigen functions. At this point linear operators are introduced and written in group form. The harmonic oscillator and hydrogen atom are also solved with the introduction of Legendre and Hermite polynomials which are developed with their properties in the appendices. The vibrations of a dynamical system are studied and applied to the case of a molecule which is treated from the aspect of a dynamical system in vibration about an equilibrium configuration. In particular, the oscillations of the water molecule are analyzed thoroughly, since it serves best to explain the theory of groups in all its aspects. In this treatment of the water molecule, there are tabular data on symmetry operations and point groups. The study of crystals is then treated.

Nuclear vibrations are studied from Raman scattering and infra-red absorption. In addition to other numerous problems in nuclear physics that are treated through the group theory, there are the applications to crystal optics, elasticity and photoelasticity, piezoelectricity and electric double refraction.

A. GOLDBERG.

PULSE GENERATORS, edited by G. N. Glasoe and J. V. Lebacqz. 741 pages, 15 × 23 cm., drawings and photographs. New York, McGraw-Hill Book Co., Inc., 1948. Price, $8.00.

"Pulse Generators", Volume 5 of the M. I. T. Radiation Laboratory Series, deals with radar modulators. The War-developed practices relating to high-power pulse radar are described for the benefit of the electrical engineer who might require microsecond pulses delivering several million watts of peak power.

High-power pulse techniques described in this book were unknown prior to the 1940's and represent solutions to problems peculiar to the use of the magnetron oscillator. Because of this a large part of the book is devoted to specialized circuits tailored to fit the requirements

of the cavity magnetron. However, the mathematical analyses are prepared in sufficiently general form to allow their application to many pulse problems which arise in the engineering routine.

The engineering of equipment for generating extremely short, high-power pulses was handicapped by a lack of workable components such as high-emission vacuum tubes. Developments of the last five years in this field alone are sufficient reason for the book's being read by even the most capable engineers whose experience falls along the lines of standard communications practice.

Suitable transformers for passing short pulses are still not commercially available. Since the engineer must design this component to exacting specifications for each application, one fourth of the book is devoted to the difficult subject of pulse transformer materials and design.

Material for this book has been collected from an impressive list of sources both industrial and institutional. The title of the book is somewhat misleading because it suggests also radar's large array of pulse circuits associated with the indicators and ranging apparatus which operate at comparatively low power. The latter material is taken up elsewhere in the series, however, and the present volume analyzes in great practical detail every significant type of power pulse generator employed so far.

C. W. HARGENS.

BASIC ELECTRICAL ENGINEERING, by George F. Corcoran. 449 pages, 15 × 24 cm., illustrations. New York, John Wiley & Sons, Inc., 1949. Price, $4.50.

If today's student is to acquire a fair share of our increased store of electronics knowledge, he needs a more comprehensive basic course in electrical engineering. Professor Corcoran wrote "Basic Electrical Engineering" to fill this need, and he succeeds very well in his primary aim.

The book is written on an elementary level throughout. But the concepts of higher mathematics required in the advanced electronics courses are introduced along with the fundamental electrical theory. For example, when a charge is moved in an electrostatic field, the work done can be evaluated precisely by using the line integral. Professor Corcoran shows also how the work can be computed by approximate methods.

In many other ways the author solves elementary problems in a simple manner by using advanced theorems. The chapter on d-c. circuit analysis explains network theorems such as the superposition theorem and Thevenin's theorem. These are applied to solve a simple attenuator problem. By easy steps the student is introduced to these powerful methods of analysis. He acquires a facility in their use which will aid him in advanced courses. In particular, the mathematical background of field theory is so framed that it can be extended in later courses to include Laplace's, Poisson's and Maxwell's equations.

The text covers elementary d-c. theory using the M.K.S. system. The subjects of voltage, current, power, resistance and capacitance are covered. In addition, the last two chapters on "Boundary Electromotive Forces" and "Non-Linear Circuit Elements" acquaint the student with electrical circuit elements such as thermocouples, batteries, vaccuum tubes and transitors.

This is an excellent college text book for elementary electrical engineering students and for engineers and physicists who wish to review their basic electrical engineering from a fresh and comprehensive viewpoint.

E. A. MECHLER.

BOOK NOTES

CATION EXCHANGE IN SOILS, by W. P. Kelley. 144 pages, 15 × 23 cm., illustrations. New York, Reinhold Publishing Corp., 1948. Price, $4.50.

In work with soils one of the properties which must be understood is that of cation exchange. In the application of fertilizers and in the turning of alkali soils into productive ones, cation exchange plays an important role. Dr. Kelley offers in this volume a survey of the principles which govern the exchange, but he does not attempt to cover the various applications. After giving a brief history, the author reviews the cation exchange materials, and the various equations which have been offered to express the cation-exchange relationship. Other chapters consider the exchange capacity of various soil types and cation exchange in relation to soil properties.

Bearing in mind the author's warning that the explanations of cation exchange advanced must be considered tentative, subject to revision as new information becomes available, the reader will find this a useful review of cation exchange in soils.

LIMITATIONS OF SCIENCE, by J. W. N. Sullivan. 192 pages, 11 × 18 cm. New York, New American Library of World Literature, 1949. Price, $0.35 (paper).

Originally published in 1933 this brief survey of science has now been made available in paper bound format which should secure it wider distribution. The author, who won considerable recognition as an interpreter of physics to the layman, was adept at analogies and in the volume brought out particularly well the imaginative aspects of scientific work.

EDUCATION FOR PROFESSIONAL RESPONSIBILITY. A report of the Proceedings of the Inter-Professions Conference on Education for Professional Responsibility held at Buck Hill Falls, Pennsylvania, April 12, 13, and 14, 1948. 207 pages, 14 × 21 cm. Pittsburgh, Carnegie Press, 1948. No price.

The conference, limited to representatives of five types of professional schools—divinity, medicine, law, engineering and business—was composed of individuals selected for their interest in improving professional education. The papers were presented at three sessions: the first on the objectives of professional education; the second on the contents and methods of professional instruction; and the third on the social and humanistic aspects of professional education.

The ideas presented are stimulating and should offer much to those interested in the problems of professional education.

MANUEL DU SAVONNIER, by A. Matagrin. Third edition, 450 pages, 13 × 18 cm., illustrations. Paris, Gauthier-Villars, 1948. No price.

This French manual of soap-making, originally published in 1938, has now appeared in a third edition. Although extensively revised for the second edition of 1943, it was not deemed expedient to undertake further revision at this time. Instead, a new forty page chapter has been appended, incorporating a summary of the major advances in soapmaking from 1943 to 1948, with numerous references to the patent literature.

Matagrin's work should serve as a useful survey of soapmaking practice, particularly for foreign techniques.

A CONCISE ENCYCLOPEDIA OF WORLD TIMBERS, by F. H. Titmuss. 156 pages, 15 × 22 cm. New York, Philosophical Library, 1949. Price, $4.75.

An English work, distributed by an American publisher, this volume contains brief descriptions of nearly 200 different timbers. Information is given on such topics as grain, texture, durability, working qualities, weight and typical uses of the timber. An alphabetical arrangement by common trade name has been used, supplemented by an index of botanical and alternate trade names. A short bibliography serves as a guide to more extensive treatments of the subject.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

Direction of Research.—ELLICE MCDONALD, Director. A research organization should follow Cardinal Manning's definition of a univeristy, "a place where enquiry is pushed forward and discoveries perfected and verified, and rashness is rendered innocuous and error exposed by the collision of mind with mind and knowledge with knowledge." This expresses the function of a research institute also with perhaps a little too much emphasis on exposure of error, as the research spirit is more concerned with the revelation of truth. In such an organization made up of scientists with great knowledge of their subjects, the director is more of a coordinating executive than one who makes hard and fast decisions. Among the group he is *primus inter pares* because some situations eventuate where some one person must make the final decision.

The qualities which make up a successful director are those of leadership in the fullest sense of its meaning. He should be sufficient of a scientist to understand the research worker's outlook. The scientific man who is keenly interested in personal research is unlikely to be the best man to choose for administrative work because his emotions are too likely to be firmly linked with his personal research, and he will find it difficult to dissociate these feelings in making judgments upon points of policy. If he deludes himself that on taking over a directorship in an organization of any size he can continue his own research, he is mistaken because the multitude of minor details requiring decision are so numerous as to prevent the constant concentration and continued application required for good research. He has no chance to do it: his job is to take on his shoulders the bothersome details and troublesome matters inherent in an organization, so that others of the group may be relieved of them and left free to devote all their concentration and energy to the prosecution of their work.

In descriptions in the literature of the qualities required for a director, it might be thought that research was a beautiful playground where he directed his team, but no mention is ever made of the multitudinous details and executive decisions required to support the background of research without which it could not function. This is because those who give such good advice about directorial qualities have rarely been directors themselves so know only the theoretical side of it.

Directorship is the art of management and, as in all arts, while there are fundamentals, each must develop his creation according to his own nature and abilities. Like any creation, it must be judged by the results. The failures and mistakes are part of the game: there are many failures for every achievement; but advance should be constant.

Any one individual cannot accomplish anything great, but through the power of organization the effect of a few may be multiplied indefinitely. The head of such a group should have a clear idea in his own mind as to the objectives to be striven for and a definite plan as the best way of reaching them. After that, success will depend upon the gift of choosing the right persons; upon the power of drawing the best out of them by encouragement, stimulation and support; upon the exercise of such a close and constant supervision over every phase without this being onerous to the workers and without getting lost in a jungle of detail, so that it is possible at all times to know how things are going. If these are going wrong, they can be corrected; if they are going right, they had better be left alone.

One scientific director may make a group do miracles; another, conscientious and not sparing himself, may reduce a group to an inchoatic medley of turmoil and dispute. He must not consider his own advancement, save for his own people; his reputation, save for his group; his comfort, save for the comfort of his fellow workers. He must not consider his own self sufficiency, but he must never forget the advancement, reputation and comfort of those over whom, by fortune, he has the direction. He must be ready to stand by his men, to take blame of any mistakes they make and to allow them the due reward of their work in recognition by their fellows of reputation and accomplishment. He must be able to recognize talent and genius when he sees them, must never claim as his own the ideas of others and he must be in easy contact with his people, not limiting his contacts to adverse criticism.

The success of a director does not come from following rules or models. It consists in a new comprehension of the dominant factors in the situation at the time and the forces at work as all problems of research are unique. The director will be wrong part of the time: but a committee is quite likely to be wrong all the time. His leadership will not consist merely in the invention of schemes, but in the selection and execution of the best.

The problem of direction is a problem of personnel and, as Hugh S. Taylor says, is resolved when a competent director is found. But the director must be responsible for his personnel and it is a wise director who makes his choices carefully.

But how shall such choices be made? It requires some experience in life and men, particularly in men seeking employment, and an extra sense as well as considerable information of the scientists who are available in the field. There must be a consuming interest in the kind of man sought and great desire to find him. His scientific proficiency must be ascertained, but in the last analysis, the director must trust to his own judgment. Then give the choice an opportunity worthy of his promise: he should have ample opportunity without restraint to develop his original and novel ideas: such checks as may be required should be

gentle and so quiet as to be almost imperceptible to him. Chance we cannot plan for: the prepared mind we can select. But as John Stuart Mill said, "Originality is one thing which the unoriginal minds cannot feel the use of."

Research work is more sensitive to the atmosphere surrounding it than most types of work. This comes no doubt from the fact that it is individual and creative. It thrives best under conditions which contribute to the contentment of the worker and his confidence in the organization. This atmosphere is supplied mostly by the director and by his contacts with his men as well as their opinion of his contacts with outsiders. This confidence comes to an organization from successful activity over a number of years and is highly conducive to morale. It should be fostered and cherished.

Nothing will inspire a man to do his best so much as an expression of confidence in his ability to do his job. When properly selected and assigned, men should feel that there is no anxiety about the results.

If responsibility is commensurate with capacity, it is important to give him freedom to make good, to show him he is responsible for the results and to show him during the progress of the work that the director is interested and is eager to give helpful suggestions and outside aid, to be sure that he is aware of conditions pertinent to his problem. He is told on his inception into the laboratory that he is a free man who will be treated as such and who is expected to live up to that designation. He is told he is expected to get along and to get along with people, that his advancement in the organization and his monetary return will depend upon his own efforts and his own achievements. When he speaks of expected salary, he is told that the policy of the organization is not to pay as little salary as possible but as much as possible, and that his discoveries and their value to the organization would be a measure of his reward and that this will be reflected in his salary. Uniformity of salary and standardization of position may be correct in teaching institutions where there is routine, but research discovery should be rewarded in proportion to its merit and to standardize research workers into categories reduces all to the level of the poorest in the category. As an old friend often quotes, "A philosopher who lived two thousand years ago said the laborer is worthy of his hire."

To aid the expression of appreciation of discovery in a material way, the Biochemical Research Foundation has instituted a bonus system which sounds very "commercial" and repulses some of the traditionalists. The description of the bonus system may be found in the NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION (JOUR. FRANKLIN INST., **238**:462, December 1944). One particular phase is the reward of exceptional research discovery and this has no limit in amount except the funds available. The idea is not so much to give a man making a discovery an amount of money, but to give him funds to ease his way in

life and family cares so that he can apply himself more completely to his work and most important to show him that there is appreciation. This is, after twenty years' experience, the attitude in which it is accepted. The plan is to give exceptional merit exceptional reward.

The problem of the direction of research is a personnel problem: the director is one who draws from his associates the best that they can give. The choice of workers will depend upon the character and scope of the research itself. Industrial research laboratories C. E. K. Mees of the Eastman Kodak Research Laboratories classifies as "convergent in distinction to the more divergent laboratories in which problems of many kinds are studied." As a matter of fact, there are few of the latter type because the scope of science is so great that there must be some limitation to the character of research lines followed; otherwise it may tend to become so diffuse as to be futile.

The rise of the industrial research laboratories is a matter of the last generation. It took some time for many in authority to understand the difference between a real research laboratory and a "shop" laboratory to check products and improve existing methods. The expenditures for industrial research in the United States had risen from a minor sum in 1914 to an amount estimated at 300 million dollars in 1939 and the number of research laboratories grew to more than 2000. The number of doctorates in chemistry was multiplied twenty or thirty times. In other words, instead of being encouraged to follow academic pursuits, young men were encouraged by scholarships and training in new technical and scientific schools to seek the greater rewards and opportunity which industrial research laboratories offered. In this way, men have been trained and developed to take up the work in an organized industrial laboratory. This is not so in biochemistry where the character of academic training is too diffuse to turn out the specialists required in organized research. Bacteriologists, it is true, come with good training from the medical schools, but, in general, in biochemistry it is better to take an organic chemist and orient him to the few exact principles of biology than to take a biologist and attempt to instruct him into the chemistry required. Until the last 20 years, chemists have taken little interest in biology and medical men in chemistry. When I joined the American Chemical Society in 1920, there were only nine other physicians in the society and for years I was the only one at the annual meetings. Now there is a change: there is a section on Medicinal Chemistry and a general interest is shown by the chemists in biological affairs. Cancer research with the advent of the discovery of the production of experimental cancer by certain chemical substances was the first to create an interest and the possibilities of chemotherapeutic substances of the type of the sulfa drugs has continued to excite the concern of the chemists in biological affairs. This is hopeful for future discoveries for, after all, life is a chemical phenom-

enon. But it all makes the place of a director of a biochemical research more necessary in the scheme of organization because he must bring together men of such diverse character and training as chemists, physicists, bacteriologists, cytologists, pathologists, etc. He becomes more of an *entrepreneur* than a director.

A director having to do with such varied special knowledge feels sometimes at a loss that he does not know as much as each specialist, but his role is not to know all about everything but to know something about all. But as he has to do with men of different training who know little about the others' specialty, it is possible, when the discussion becomes too abstruse in, for example, the region of chemistry, to take the conversation over to the area of physics or cytology and if the physicist becomes too complicated, to drag him over into cytology of which he knows little.

Then if this fails, ask the chemist, "What is the kinetics of the reaction?" That never fails to set them off. Or the physicist, ask him, "What really is a neutrino?" As the neutrino is something which is not known to exist but is presupposed on account of the charge required to be compensated, it takes some explanation and enables the director to recover his equilibrium. Pasteur used what he called "the method of ignorance" in pretending to be ignorant and compelling his pupils to make a full statement to inform him. It often clarifies the subject.

Highly desirable though it be that he have some understanding of the technique of research, an able director, cognizant of the importance of technological advance may make good his own deficiency by the selection of assistants who are familiar with the new methods and the new equipment. Our practice often has been to bring in specialists from outside to instruct our people in certain new techniques. For example at the time when enzyme chemistry was at its infancy in this country, we brought a laboratory of four enzymologists from Europe in order to get a flying start in this important phase. Then we sent over people to learn new and elaborate techniques such as the Linderstrøm-Lang microchemical technique in Copenhagen, the Tiselius electrophoretic technique in Upsala and so on. It is better to go to learn these complicated manipulations at first hand and if possible bring back a pupil who has worked with the discoverer. This saves a lot of mistakes in a new set-up. One important matter is to get the right person on the right job. It often appears that a man will do well on one phase where he will do badly on another. He is "miscast" to use a phrase of the theatre and he should be given another part.

The direction of research should never follow a rigid plan. There should always be a consideration of alternative objects and of the advances which have taken place in the sciences. It is very like the strategy of war. In past times the type of war was the rigid phalanx of the Greeks and this was overcome by the light troops of the Romans,

used as an accessory on a fixed base. The flexible Roman order in the second Punic war was incapable of coping with the real power of Hannibal's army placed in its elastically hinged cavalry wings. Scipio recognized the fundamental flaw in the Legion tactics and created an effective cavalry arm and developed a superior infantry pivot. The stalemate trench warfare of World War I has given way to the flashing attack by plane and tank of World War II which no doubt will in turn be altered by the atomic bomb.

So in organization of the research attack, the director must consider his forces and his implements; must plan his strategy to advance here, to hold fast there, to find place in the front where he can concentrate his forces with the hope of a break-through in the front of research which will lead to a victory in discovery. It is more and more the problem of concentration in action and a new understanding of the problems of alternatives, that is, the adaptabilities of objectives. Napoleon once said, "If the art of war consisted merely in not taking risks glory would be at the mercy of very mediocre talents." There is a distinction between strategy and tactics and the director must have a touch of the gambler in him, for research is an adventure. He must act as if failure was impossible, not begin a venture timidly or, on meeting difficulty, retreat from it with discouragement. Once started, be determined to carry the project through, working unceasingly and meeting every obstacle with undaunted resource. It is difficult to do any new thing: to follow old programs is easy. Research follows no constant pattern, pursuing it and thinking about pursuing it are different processes. There is a pattern but there is no logic in research into vital processes just as there is a pattern in life itself.

In discussions with fellow workers it is well to remember these two definitions: a hypothesis is a proposition put forth merely as a basis for reasoning and argument. A theory is a scheme or system of ideas held as an explanation of a group of facts, a hypothesis which is confirmed by observation or experiments. It makes for clarity of thinking and ease of discussion to remember the essential difference in meaning between these two phrases. As Poincaré said, "A collection of facts is no more a science than a heap of stones is a house." Verified knowledge is necessary to the testing of hypotheses.

The course of a laboratory should depend upon its objectives. The mean should be between the brilliantly useless and the cheaply practical. If a matter is being well studied in another laboratory, it should be left to them for, in scientific research, duplication is a crime.

It is better to choose what can be well done with the means at hand rather than use a counsel of perfection which may take years to accomplish. Fashion in research affects laboratories as well as people and the tendency is for all to run in one direction following some interesting discovery and elaborating it. This is depressing to origi-

nality and should be forfended against. While men are working on one project, their thoughts should be prepared for some new phase in the future by discussion with them to arouse their interest in the future and in possible developments. They will then approach the new phase with eagerness and zest.

The object of direction is to improve existing arrangements not violently nor abruptly, but by sanity, soberly commensurate with the needs of the organization. Violent upheavals are very upsetting to an organized group. Reforms are best that come naturally and with least friction when men's minds have become ripe for them. Bacon in his essay "On Innovations" points the way to research organizations and to governments also:

> "It were good that men in their Innovations would follow the example of Time itself, which, indeed, innovateth greatly, but quietly, and by degrees scarce to be perceived. . . . It is good also not to try experiments in States except the necessity be urgent, or the utility evident; and well to beware that it be the reformation that draweth on the change, and not the desire of change that pretendeth the reformation."

The progress of ideas, if it is true progress, depends upon cooperation to a high degree but this does not mean subordination or that subordination can be a substitute. In this sphere the leader may still be essential, but instead of fusing individuals into a mass through suppression of their individuality and contraction of their thought, the effect is in proportion to the elevation of individuality and the development of the research imagination so that their presentiments may often come true. Collective growth is only possible through the freedom and enlargement of individual minds. In all efforts luck or chance enters: the man makes the best use of his opportunities and the material at hand. Huxley said, "Life is like a game of cards, we are dealt a hand of varying value and left to play the game as best we can." It is perhaps more pungently stated in the epitaph burnt in on the headboard of the cowboy's grave, "Life ain't holding a good hand but playing a Pore Hand well. He done his Damdest, Angles cud do no more."

CURRENT TOPICS

Radar Reflections.—Mysterious radar reflections which have baffled the world's electronics experts both during and since the war have been explained by scientists of Bell Telephone Laboratories. The cause: flying insects.

Nicknamed "angels," the heretofore unexplained "blips" have shown up confusingly on many radar scopes as sharp echoes of short duration, observable most frequently below heights of 3000 ft.

The explanation that the "angels" are caused by flying insects is contained in a communication to the April issue of the *Proceedings of the Institute of Radio Engineers* from A. B. Crawford of Bell Telephone Laboratories. The strange reflections were discovered during the war by M. W. Baldwin, Jr. also of Bell Telephone Laboratories.

Since that time, they have been the subject of considerable research. A number of observers have suggested they were due to atmospheric changes which result in turbulent motion in the lower atmosphere.

The tests and observations reported were sponsored jointly by Bell Laboratories and the Naval Electronics Laboratory and were conducted at Gila Bend, Arizona. Working on the problem, besides Crawford, were L. R. Lowry and S. E. Reed of the Bell Laboratories technical staff, and Dr. J. B. Smyth and L. J. Anderson of the Naval Electronics Laboratory.

Crawford's investigation of "angels" was undertaken as part of fundamental studies of microwaves which are being increasingly used to carry telephone messages and television programs over the nation's communication network. Most radar equipment operates in the microwave region.

In his communication, Crawford wrote that he was led to the conclusion that the reflections were caused by insects "when all attempts to synthesize 'angels' by artificially producing boundaries of temperature, humidity or turbulence failed completely and when visual observations of insects coincided strikingly with the radar observations."

In their attempts to synthesize the strange patterns on the radar scopes, the scientists exploded a small charge of nitro-starch in the air, 500 ft. above their radar antennas. They flew a plane low over the radar and looked for reflections from the exhaust gases. They built bonfires, upwind, so that the hot combustion gases and steam clouds formed by pouring water on heated rocks billowed into the beam. In all these experiments, the phenomenon was never observable.

Later, working at night, they threw out a strong searchlight beam, and stationed observers at different levels of a 200-ft. tower. While the observers counted insects, the radar operators counted the appearance of "angels" on their scopes. For example, in one 15-min. period, twenty were counted, fifteen of which coincided with the sighting of an insect.

Crawford points out that insects fit most of the descriptions which have been applied to the mysterious reflections on radar scopes. They are small, they move at a speed comparable to wind velocity, sometimes with and sometimes against the wind, they are present both day and night, and there are more of them in warm weather than in cold.

New Dry Cell Has Longer Life (*Aminco Laboratory News*, Vol. 6, No. 1).—A new dry battery that is lighter and longer-lasting because it uses oxygen from the air instead of from chemicals within it was announced recently by Dr. Lauchlin M. Currie of the National Carbon Co., New York. Persons who wear electronic hearing aids will be the first to benefit from this development. The new "A" battery weighs about an ounce and lasts 80 hours—three times as long as the slightly heavier cell it replaces.

"The new unit offers the largest output of electrical energy in the lowest weight and volume ever delivered in a commercial battery," Dr. Currie explained. No metal oxides are used as the depolarizing agent which keeps the battery from stalling. This effect is secured by using a highly active carbon electrode that takes up oxygen from the air when the battery is unsealed for use. A paste around the electrode holds the necessary electrolyte which, in effect, is regenerated. The battery continues to operate until the pure zinc anode is used up in the chemical action that produces the electricity.

New Plastic Highly Resistant to Chemicals (*Aminco Laboratory News*, Vol. 6, No. 1).—Fluorine and chlorine make up by weight four-fifths of a new plastic known as Kel-F, made by the M. W. Kellogg Co. It is an unusually stable, high-temperature material of the thermoplastic type, extremely resistant to chemical action. It is strong and hard, but not brittle, and while particularly suitable for use at relatively high temperatures, gives satisfactory performance at low temperatures. The new plastic is chemically a polymer of trifluorochloroethylene.

New Molding Machine Introduced.—A new, low cost molding machine for experimental molding of plastics for those who wish to do injection molding of "Bakelite" styrene plastics and other thermoplastic material in workshops, laboratories, schools and other places is being announced by Plastics Development Corp., 225 Lafayette Street, New York 12, N. Y. This injection molding machine is designed for use with a drill press; is simple to install and easy to operate. The new equipment eliminates expensive preparation and is ideal for short runs and experimental work. Built for heavy duty, it is equipped with standard heating elements, thermostatically controlled with range from 250 to 500° F. The machine has $\frac{1}{4}$-oz. capacity, is 10 in. in height, weighs only 2 lb., has a 3-in. stroke, and is ready for immediate use in any 110–125 a.c.–d.c. outlet.

Automatic Blood Pressure Recorder.—A piece of medical apparatus, devised a decade ago and in use since that time, has been recently introduced to the public. The instrument is an automatic blood pressure recorder and its inventor is Dr. Warren E. Gilson, assistant professor of medical electronics at the University of Wisconsin Medical School.

Dr. Gilson also received considerable attention in 1945 for developing a "bullet finder" for treating wounded soldiers in combat areas during World War II.

The recorder was patented July 3, 1945, but Dr. Gilson explains that the first model was made in 1938. The patent has been turned over to the Wisconsin Alumni Research foundation.

The blood pressure recorder operates on the same principle as the manual apparatus, using an inflatable cuff on the patient's arm. However, the rising and falling of the blood pressure as the heart contracts and relaxes is recorded on a moving graph by a penwriter. A second penwriter is controlled by a stethophone, which picks up and records the intensity of the blood pressure sounds.

"The automatic recorder minimizes patient discomfort by sudden and automatic release of cuff pressure," Dr. Gilson explained.

"Also, it is possible to get an accurate and simultaneous record that may be kept and studied. The machine can be set to take readings every 30 seconds, 60 seconds, five minutes, 30 minutes, or 60 minutes. The doctor need not be in the room when readings are taken. This aids in keeping to a minimum the psychological reactions all patients exhibit. It has been noted that blood pressures jump when the doctor re-enters the room," Dr. Gilson said.

Dr. Gilson pointed out that the machine finds good use in the operating room by enabling the anesthetist to keep a check on the patient's blood pressure and heart action without abandoning his other duties.

The machine also may be used to chart respiration and can be rigged for use as a lie detector.

Machine to Play Chess.—A Bell Telephone Laboratories scientist recently described at a meeting of The Institute of Radio Engineers, techniques whereby a computing machine might be made to play a first-rate game of chess.

The telephone scientist, Dr. Claude E. Shannon, pointed out that his interest in mechanical chess is purely theoretical.

"We are not designing chess equipment at Bell Telephone Laboratories," Dr. Shannon declared. "But in the telephone business we are faced with many mathematical and statistical problems. By studying the theory of using an electronic computer to play chess, we expect to find solutions to some of our telephone engineering problems."

He specifically mentioned the possibilities of improved methods of routing dial telephone calls. He also suggested that, as a result of these studies, computers might be made to turn out, automatically, designs for electrical relay circuits, filters, equalizers and other equipment widely used in telephone systems.

Dr. Shannon told the Institute's members that a solution of the mechanical chess problem "will force us either to admit the possibility of mechanized thinking or to further restrict our concept of thinking."

In order to play chess of master caliber, Dr. Shannon said, the electronic computers now in use would have to be improved somewhat, but with those now available a game skillful enough to interest the average amateur player would be possible. A machine would have three advantages over a human player, he said: high-speed operation, freedom from errors and freedom from laziness. As to the last factor, he said that it is "all too easy for a human player to make instinctive moves without proper analysis of the position."

Millionth of an Inch Adjustment Possible (*Steel*, Vol. 124, No. 16).—Rapid adjustments in terms of millionths of an inch may be made by fingertip control on a new 12-ton precision jig borer installed in the plant of Baker Brothers Inc., Toledo. One of two machines of its kind in this country, it is so delicately balanced that the 1-ton table on which the parts are rolled beneath the boring head could be pushed with the pressure on one finger, if it were disconnected from the rest of the machine.

Measuring scales placed above and below the boring head allow the operator to line up the parts to be drilled with extreme accuracy. A series of lenses and prisms magnify and illuminate the delicate graduations of the scale. Use of the machine reportedly will allow the company to drill the most accurate parts in this country.

Before installation was made six windows of the Baker plant were bricked up to keep out rays of sun which might affect the accuracy of the machine. It will be enclosed in an air-conditioned room for protection from dust and temperature as well as protection from sunlight.

Pneumatic Tool Lift Reduces Wear, Improves Operation (*American Machinist*, Vol. 93, No. 8).—A 12-ft. planing machine in the Mackenzie Bros. plant at Sydney, Australia, has been fitted with an air-operated tool lift for the last two years. The lift has an impressive number of advantages—it has saved 25 per cent of normal tool wear, 10 per cent in work time, made possible the use of tipped tools and improved finish on mild steel, aluminum and cast iron by 50 per cent increased accuracy on long cuts, and is economical to operate.

An air cylinder is mounted on the slide of the machine by means of a hinge pin which permits it to rock. The spring-loaded plunger is fitted with a loop end which forces the tool out and up, and also allows some play in case of accidents. A single air inlet, admitting line air at 100 psi., is located in the top wall of the cylinder.

Two valves, inlet and outlet, are mounted on the machine in front of the feed rack and both feed directly to the air cylinder through a single line. Valve trips, made from nuts and bolts, are mounted on the feed rack in slotted (for adjustment) plates. On the cutting stroke the rack lifts up and the top trip contacts the exhaust valve to evacuate the cylinder. Spring pressure brings the tool smartly down to cutting position. On the return stroke, the other trip hits the inlet valve which fills the cylinder and forces the tool and mount out and up away from the work.

The clapper lifts smoothly and returns to position rapidly, and more than one tool can be operated with the same mechanism. The cylinder can easily be removed from one installation and changed to another.

Variable Resistor Combines Two Controls on Concentric Shafts (*Design News*, Vol. 4, No. 4).—the Midgetrol Dual, announced by P. R. Mallory & Co., Inc., is a compact, dual, variable resistor for television and other applications. It combines two quiet, compact controls on concentric shafts. The small size of the unit, $\frac{15}{16}$-in. diameter, makes it possible to move several key television adjustments from the rear of the chassis to the front. Eight single controls now required to make adjustments on the average television receiver

can be changed to four Mallory Midgetrol Duals, thus permitting any of them to be moved to the front of the chassis.

The resistor is fully insulated for high voltages encountered in television. It incorporates a special low-drift resistance element to meet temperature-humidity drift problems. The two-point shaft suspension, which permits use of shorter bushing, provides more stable resistance values, less danger of damage in assembly, longer life; it also permits specification of longer shafts.

Genes Seen for First Time (*Instrument Practice*, Vol. 3, No. 5).—It was recently reported in the *New York Times* that genes, which transmit physical characteristics of living things from one generation to another, have been seen and photographed by two scientists of the University of Southern California, Doctors D. C. Pease and R. F. Baker, who described the genes as thin, double-pointed "spindle-shaped" particles one one-hundredth of a centimeter long and one one-millionth of a centimeter wide.

Observations were made with a standard electron microscope on unbelievably thin cross-sectional slices of animal tissue obtained by a new cutting technique. By hardening the tissue specimen with paraffin, collodion and air chilled by dry ice, and using new methods of adjusting the cutting blade, the scientists said, they obtained slices only 1/250,000th of an inch thick, permitting for the first time the penetration of electrons necessary to disclose the genes.

Insecticide Laboratory.—Eight thousand flies and not a fly swatter in sight!

Add a few thousand cockroaches and clothes moths, hundreds of pea aphids and army worms and you have some idea of one of the most unusual laboratories in the world.

The Wisconsin Alumni Research foundation (WARF) insecticide laboratory at the University of Wisconsin campus at Madison is probably the only place where more than 20 species of insects are produced by "assembly line" methods.

The tiny pests are treated with almost loving care for, contrary to popular opinion, they're delicate creatures. They're susceptible to diseases, must have just the right kind of food, and they thrive only if the temperature is carefully controlled. Visitors at the laboratory are warned not to frighten the insects because this weakens them. There are no rules about the insects frightening people.

The purpose of all this tender care is, of course, to produce healthy insects to be used in testing insecticides. The WARF laboratory serves as an impartial testing organization for insecticide manufacturers, chemical industries, and anyone else interested in the field.

Keeping enough insects on hand for the tests is probably the biggest job of the laboratory. Each day it must produce some 8,000 adult flies, about 1,000 cockroaches, 1,000 clothes moths, 500 pea aphids, and hundreds of milkweed bugs, red spiders, carpet beetles, and similar insects. Not only that, it must anticipate its needs several weeks in advance, for insects are not produced full-grown. At any moment you can find each type of insect at each stage of development somewhere in the lab.

The insects have been carefully selected to represent various insect families, since those within a family are usually similar in their susceptibility to insecticides. Cockroaches, for example, represent the grasshopper family.

The number and kinds of insects that can be raised are limited by food. Some insects, like the corn borer, need a host plant to live on and won't accept a substitute. Although the production room looks like a miniature hot house, Dr. Kido says full-grown corn plants would be too much.

Raising food for some of the finnicky guests is a big job in itself. Pea apids, those tiny green specks that suck the life out of pea plants, are fed tender, juicy plants. They're kept in a separate room, maintained at 60 degrees Fahrenheit, because this temperature is best for both the plants and the insects.

Other types of plants are raised in sterile, exploded mica on culture tables in the insectary. For 14 hours each day fluorescent lights pour energy into them while absorbent cotton wicks keep them supplied with water. As soon as they're the proper size, they become food for the insects.

The laboratory workers have found that dog biscuits are almost perfect food for cockroaches and clothes moths are fed wool treated with vitamin B.

One of the most unusual insects in the collection is the milkweed bug. It lives entirely on milkweed seeds which it digests outside its body. By inserting two tubes into the seed, Mr. M. B. shoots an enzyme into it with one and draws out the digested products with the other. The only problem is to keep him supplied with milkweed seeds.

The laboratory runs tests on all types of insecticides: water sprays, suspensions, oil sprays, dust mixtures, and agricultural chemicals. Both crude products and finished sprays are tested.

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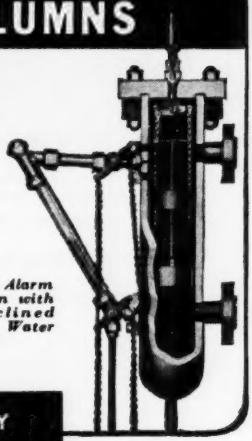

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All persons interested in the purposes and activities of the Institute and willing to further them, may become members when elected by the Board of Managers or in a manner prescribed by the Board. The following classes of membership are provided for in the By-Laws: Student, Associate, Active, Sustaining, Honorary.

Sustaining Members belong to the highest class of membership in the Institute and are entitled to all privileges of membership including Family Privileges. They are included among the Friends of Franklin, a group of public spirited citizens who contribute to the support of the Institute and in other ways call the attention of present-day Americans to the wisdom of Benjamin Franklin.

Sustaining Membership.....(annually) $50.00 or over

Active Members have the full use of the Library with the privilege of borrowing books. They are entitled to vote and to hold office. Subscription to the *Journal of The Franklin Institute* is included in their dues and they are sent each month a copy of *The Institute News* which contains a program of events and other items of interest. Their membership cards also entitle them to admission free of charge to the Museum, the Planetarium and the Museum demonstrations and lectures. Active Members who reside permanently at a distance of 50 miles or more from Philadelphia are permitted to pay annual dues of $7.50.

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Associate Membership.....(annually) $5.00
" " with Family Privileges.....(annually) $10.00

Family Privileges may be obtained by Associate or Active Members on payment of $5.00 annually in addition to their regular dues. This entitles them to receive, for each individual in their family and resident with them, a card entitling the holder to unlimited free admission to the Museum and Planetarium.

Student Members must be under twenty-five years of age. They are entitled to all the privileges of Associate Membership except Family Privileges. On payment of an additional amount and on the sponsorship of a teacher or an Active Member of the Institute they may be granted the use of the Library.

Student Membership.....(annually) $2.00
" " with use of Library.....(annually) $3.00

Membership for Life may be obtained in the Associate and Active Classes on payment of $100 and $300 respectively. For those who reside permanently at a distance of fifty miles or more the fee for Active Membership for Life is $100.

The annual fees for membership are due and payable on the first day of the month of the date of election, or as determined by the Board of Managers. Any member whose dues are more than two months in arrears shall have all the privileges of membership suspended until such time as all arrears are paid. Should the dues not be paid when they become six months in arrears the said member shall forfeit his membership.

Firms, Corporations, Associations or **Individuals** may nominate and subscribe for the membership dues of groups of members of any class or classes, at the annual dues provided for, subject to the approval of the Board as to any particular nominee. If the dues of these nominees amount to $100 or more in the aggregate, the firm, corporation, association or individual shall be known as an Affiliate of the Institute.

Resignations of memberships shall be made to the Board of Managers in writing, but need not be accepted until all dues and arrears up to the date of resignation have been paid.

For further information and membership application blanks address the Secretary, The Franklin Institute, Benjamin Franklin Parkway at 20th Street, Philadelphia 3, Pa.

AWARDS BY THE INSTITUTE

The Franklin Medal (1914—Gold Medal).—This medal is awarded annually from the Franklin Medal Fund, founded January 1, 1914, by Samuel Insull, Esq., to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications.

The Elliott Cresson Medal (1848—Gold Medal).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (1906—Gold Medal).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles.

The John Price Wetherill Medal (1925—Silver Medal).—This medal is awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods already known.

The Edward Longstreth Medal (1890—Silver Medal).—This medal is awarded for inventions of high order and for particularly meritorious improvements and developments in machines and mechanical processes. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance.

The Louis E. Levy Medal (1923—Gold Medal).—This medal is awarded to the author of a paper of especial merit, published in the JOURNAL OF THE FRANKLIN INSTITUTE, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance.

The George R. Henderson Medal (1924—Gold Medal).—This medal is awarded for meritorious inventions or discoveries in the field of Railway Engineering.

The Walton Clark Medal (1926—Gold Medal).—This medal is awarded to the "author of the most notable advance in knowledge or improvement in apparatus, or in method concerning the science or the art of gas manufacture or distribution or utilization in the production of illumination, or of heat, or of power."

The Frank P. Brown Medal (1938—Silver Medal).—This medal is awarded to inventors for discoveries and inventions involving meritorious improvements in the building and allied industries.

The Newcomen Medal (1943—Gold Medal).—This medal is awarded, not oftener than once in three years, for achievement in the field of Steam.

The Francis J. Clamer Medal (1943—Silver Medal).—This medal is awarded at least once in five years for meritorious achievement in the field of Metallurgy.

The Stuart Ballantine Medal (1946—Gold Medal).—This medal is to be awarded in recognition of outstanding achievement in the fields of Communication and Reconnaissance which employ electromagnetic radiation.

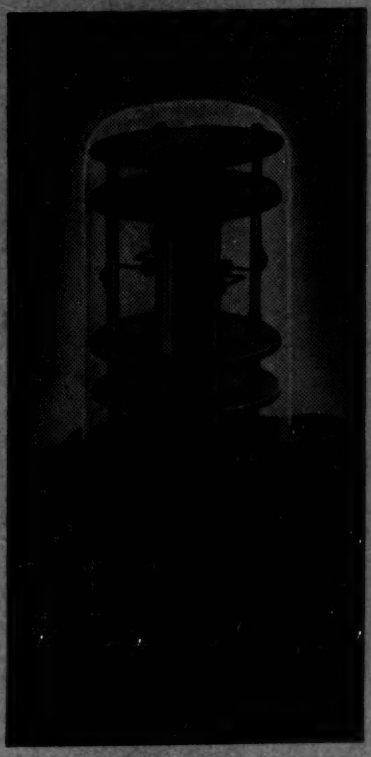
The William M. Vermilye Medal (1937—Bronze Medal).—This medal is awarded biennially in recognition of outstanding contribution in the field of Industrial Management.

The Certificate of Merit (1882).—A Certificate of Merit is awarded to persons adjudged worthy thereof for meritorious inventions, discoveries or improvements in physical processes or devices.

The Boyden Premium.—Uriah A. Boyden, Esq., of Boston, Mass., has deposited with The Franklin Institute the sum of one thousand dollars, to be awarded as premium to "any resident of North America who shall determine by experiment whether all rays of light and other physical rays are or are not transmitted with the same velocity."

For further information relating to these awards apply to The Executive Director.

(Revised to April, 1948.)



Key to a Crystal Gateway

At left is a coaxial circuit crystal in its glass enclosure. Above the crystal is shown, 3½ times actual size, with connecting wires soldered in position. Weights on wires reflect energy back into crystal, so exit leaves.

How would you solder a wire to a crystal? This must be done for most of those wafer-thin plates of quartz used in electrical circuits. They play a big part in the myriad-channel telephone system that utilizes coaxial cables.

This is how Bell Laboratories scientists solved the problem: A spot of paste containing silver is deposited on the crystal and bonded to it by oven heat. The crystal is then vapor-plated with a thin layer of silver. Then a fine wire is soldered to the spot by a concentrated blast of hot air. The result is a rugged electrical connection to the surface of the crystal which does not interfere with its vibrations.

Sealed in glass tubes, the crystals are precise and reliable performers in the telephone system. Each is a crystal gate to a voiceway, separating *your* conversation from the hundreds of others which may be using a pair of coaxial conductors, at the same time.

This spot of paste, this tiny wire, this puff of air are among the tremendous trifles which concern Bell Telephone Laboratories in finding new ways to improve your telephone service.

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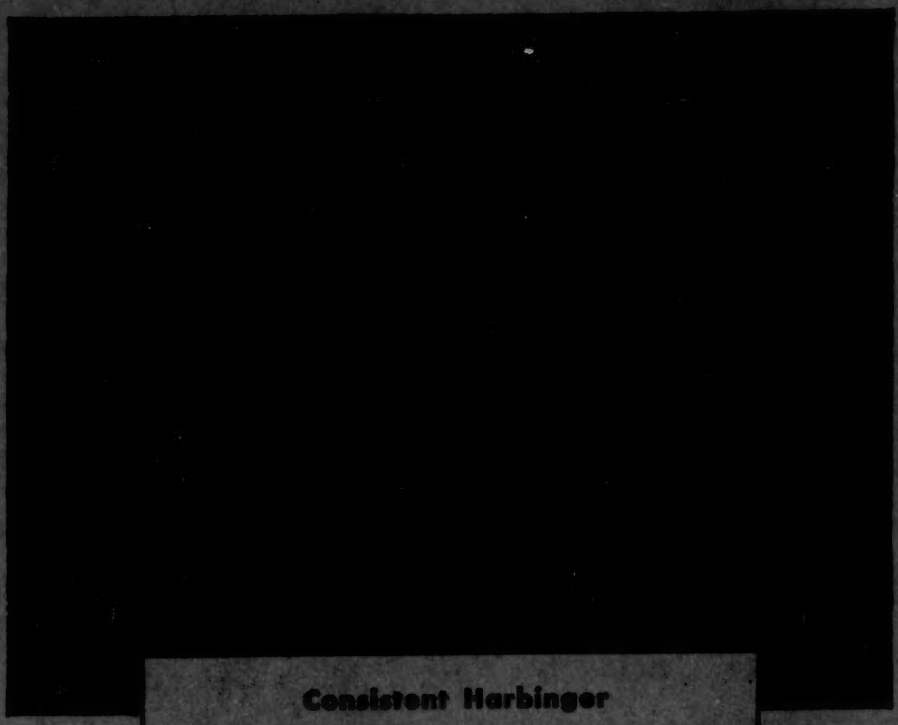
Exploring and Inventing, Devising and Perfecting, for Continued Improvements and Economies in Telephone Service



Consistent Harbinger

It is interesting to observe how the industrial philosophy of The Budd Company, of building better products through the use of superior materials and challenging design, not only stimulates its own growth, but actually alters the course of entire industries.

Invention of the steel automobile body by Budd marked the end of wooden bodies—and Budd is today the world's largest independent producer of automobile body components.

Where would you find, today, the once-universal wooden automobile wheel? Introduction of the steel disc wheel by Budd marked the beginning of its extinction.

Railway trains grew to prodigious, impossible weights until Budd built the first lightweight, stainless steel train in 1934. Now the entire car-building industry is committed to lightweight construction. And in only fifteen years Budd has grown to be the world's second largest railway passenger car builder.

Most recently Budd has become active in the improvement of subway cars. A prototype, ten-car, all-stainless steel subway train was delivered in April to New York City's progressive Board of Transportation. In view of previous developments which have stemmed from Budd enterprise, subway operators may look forward to the creation of more efficient, economical equipment, and subway riders to much-improved service. The Budd Company, Philadelphia, Detroit.

Budd